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DEVELOPMENTAL PROCESSES AND ENERGETICS

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I. INTRODUCTION

AN EMBRYO in its development undergoes a series of complicated changes which proceed automatically towards a well defined goal. To investigate the causes of these changes it is important to learn something of the energy changes involved. There exists considerable information as to the heat production, respiration, etc., of developing embryos. This, with the exception of the more recent work, has been comprehensively covered by Needham (1931) in his treatise on *Chemical Embryology*. In the present article the question of the relation of the energy transformation to the developmental changes will be examined. It will be necessary first to discuss the relation between the various processes that may be assumed to be exhibited by the developing embryo.

The adult form of an organism is a system that is evidently out of equilibrium with its environment. It requires the expenditure of energy to maintain it in a steady state. This process of preserving the form and properties of the adult organism is called maintenance. It may be presumed that the developing embryo, although it is not in a steady state, also exhibits maintenance in addition to processes resulting in increase in amount of living material (growth) and in change of form and composition (differentiation). That maintenance, growth and differentiation can be distinguished conceptually does not necessarily mean that they are distinct in the embryo. These processes and their components can, however, also be distinguished experimentally in the developing embryo to some extent. An excellent survey of experiments illustrating such separation or dissociation of the various developmental processes has been presented by Needham (1933). Making use of the notion of hierarchical order, Woodger (1930, 1931) has given a logistic analysis of the primary developmental process. Another interesting analysis that may be mentioned is that given by Weiss (1939). Different investigators differ somewhat in their conceptions of these processes. We shall present our own views here without attempting to determine to what extent they differ from or coincide with those of other writers and shall examine some of the evidence concerning dissociability of these processes. Since the cases illustrating dissociation should furnish material for an investigation of the energy requirements, the evidence must be examined rather critically.

II. THE DEVELOPMENTAL PROCESSES AND THEIR SEPARABILITY

1. Maintenance

By maintenance is meant the process of keeping an organism in a steady state. An adult organism in a "resting condition" is considered as exhibiting

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maintenance. Also a ripe unfertilized egg would illustrate this. The basal metabolism of an adult organism is ordinarily taken as a measure of the energy requirement for its maintenance, but this has certain implications which will be considered later. The question here is whether or not there is justification for the assumption of maintenance as a distinct process in the developing embryo. This rests on whether or not it is possible to block development in a reversible (non-destructive) manner; that is, in such a manner that there is complete recovery and normal development after the block is removed.

2. Naturally occurring quiescent periods

A reversible blocking of development is exhibited in the normal development of many forms of animals. In mammals, for example, quiescent periods have been reported in the blastocyst stage of the development of the roe-deer, the armadillo and the badger (Hamlett, 1933). In grasshoppers and other insects we find the phenomenon of diapause in which development ceases for a considerable period. This dormant period can be eliminated experimentally (Slifer, 1932). In an atherine fish called the Grunion (*Leurisithes tenuis*), which is found along the coast of Southern California, there is also a dormant stage in development. The eggs of this fish are buried in the moist sand of the beach and develop there up to the time of hatching. They do not hatch out unless they are washed out of the sand. They can be kept in this stage in the sand for at least two weeks and still be capable of hatching when placed in sea water (Clark, 1938). Dormant periods which may extend over years occur in branchiopod Crustaceans (e.g. *Artemia*, *Daphnia*, etc.) and in the rotifers. These forms produce so-called winter eggs which can withstand adverse conditions (drying, cold, etc.) and in which development is blocked at an early stage.

In the various naturally occurring cases the resting phase occurs at a definite stage in development, usually either a very early or a very late stage. It would be desirable to show that development can be reversibly blocked at any stage. The evidence on this point is not as complete and satisfactory as might be desired.

3. Experimental blocking of development

Low temperature, as has long been known, blocks development at any stage. But the different stages give quite different results in regard to recovery after blocking. It is well known, for example, in hen's eggs that the time of storage at low temperature that will permit subsequent development, decreases very rapidly upon incubation. Also it has not been shown that in these later stages there has been a complete stopping rather than a considerable retardation of development. Only in the case of the unincubated egg has recovery after prolonged and evidently complete blocking by low temperature been demonstrated (Moran, 1925). It is suggestive that the unincubated chick embryo corresponds roughly to the blastocyst stage of mammalian embryos and it is in this stage that normally occurring dormant periods have been described.

Anaerobiosis is another agent that will block the development of animal eggs. But the question of recovery after complete blocking has not been extensively investigated. It is complicated further by the fact that development may occur to some extent under the anaerobic conditions. In the case of the sea-urchin egg this is very slight, but in the frog cleavage may proceed up to an advanced blastula stage (Lennerstand, 1933; Brachet, 1934). Development may also be stopped by such agents as cyanide, carbon monoxide, ether, the urethanes, etc., but the evidence on the resumption of development is again incomplete.

Acidifying the sea-water will block the development of sea-urchin eggs. Resumption of normal development, however, is only possible if the block is of very short duration (Tyler and Scheer, 1937).

Short exposures to very dilute mercuric chloride solutions will block cleavage of sea-urchin eggs (Hoadley, 1930). This block can be reversed according to Rapkine (1931) by immediate transfer to sea water containing cystein. It was not determined whether reversal is obtained after a prolonged period of blocking or only after a very short period.

Dinitrophenol (and other substituted phenols) will reversibly block the development of eggs of marine animals (Clowes and Krahl, 1934). This appears to be the best agent so far investigated. Development may be resumed after as much as 36 hours of complete cessation (unpublished data). This is as long as the unfertilized egg lives under ordinary conditions

The fact of the limited length of life of the unfertilized egg, and of the adult organism as well, raises some questions concerning the significance of maintenance to which we shall return. The point to be

made here is that the demonstration of maintenance as a distinct process in the developing embryo does not rest on obtaining an indefinitely long reversible block.

4. *Separation of maintenance and growth*

The so-called "resting bacteria" (Quastel and Whetham, 1924) have been considered a good example of the separateness of maintenance and growth. Although they do not multiply these organisms are capable of accomplishing many of the enzymatic processes of actively dividing cells. Recovery of the power of reproduction does not occur to any appreciable extent, and on this basis one may not be justified in considering these bacteria alive A better instance is perhaps that reported by Gegenbaur (1921, cited by Rahn, 1932) in the study of disinfection of bacteria (*Micrococcus pyogenes*) by $HgCl_2$. The bacteria after treatment with $HgCl_2$ are not immediately killed but enter what may be called a dormant stage. They will recover and grow after several hours dormancy when treated with H_2S, whereas washing with water is ineffective in reviving them even after a very short dormant period.

Another line of evidence is found in the nutrition and hormone studies on growing organisms. Most of the work does not quite bear on the point under discussion since the effects studied are usually retardations rather than complete cessation of growth. For example, in the classical case of extirpating the hypophysis (Allen, 1916; Smith, 1916) growth proceeds although at an extremely slow rate.

In experiments on amphibian tadpoles fed on various amino-acids, singly and in combination, in addition to a non-nitrogenous "basal" diet, Gudernatsch (1937) presents evidence for the separateness of maintenance, growth and differentiation. On the "basal" diet alone the tadpoles soon die from starvation. The addition of certain amino acids prolongs the life span without appreciable growth and differentiation. Others tended to support growth and others furthered differentiation. The general results are listed in Table 1. Quantitative data are not given as to the extent to which the tadpoles may survive without growing or differentiating, but the results show the possibility of prolonged survival in a static embryonic condition. Similar differential effects on maintenance, growth and differentiation have been described in an extensive series of investigations by Hammett and his co-workers (1940) who have studied the rôle of amino-acids and nucleic acid components in bud development in the colonial hydroid *Obelia geniculata*.

The best illustration of the separateness of maintenance and growth appears in the work of Osborne and Mendel (1914, 1915). Young rats fed on certain purified proteins such as gliadin, in addition to an adequate non-nitrogenous diet fail to grow but remain healthy and well-formed. They may be kept at constant weight for as long a time as would normally cover their entire growth period and still be capable of resuming growth. The addition of lysine (Osborne and Mendel, 1915) or of cystine (Woods, 1925) to the experimental diet permits resumption of growth. Work along this line has been greatly advanced in recent years by the use of purified amino-acids instead of incomplete proteins (see review of Rose, 1938).

TABLE 1

Gudernatsch's (1937) classification of amino-acids on the basis of feeding experiments on frog tadpoles

Glycine, Alanine, Leucine	Support maintenance (best)
Aspartic acid, Glutamic acid	may support maintenance (was toxic)
Arginine, Lysine, Cystine	Support growth (best)
Phenylalanine, Tyrosine, Tryptophane	Support differentiation
Histidine	may support differentiation (was toxic)
Proline	

This work on young mammals distinguishes principally between maintenance and growth since organogenesis is completed long before the start of the experiment.

5. *Experiments showing non-dissociability of maintenance*

While the above cases tend to show the dissociability of maintenance in the developing organism, there are numerous experiments in which its intimate relation to growth is manifest. It has been shown, for example, that young dogs held at con-

stant weight by restricting the food supply (Aron, 1910, 1911) would die of starvation unless the food were increased sufficiently to permit some gain in weight. Similarly, newborn rats, if maintained at their birth weight, would die in a limited time (Stewart and Jackson, 1920). In young steers, maintained at constant weight, it has been found (Waters, 1908) that the height and length of the animal increases, there being a depletion of fat reserves.

It has been possible also to build up a "growth debt" by keeping young rats at constant weight for varying periods of time (Thompson and Mendel, 1917). Upon return to normal diet the experimental animals grow at an extremely rapid rate and catch up with the controls. This great acceleration of growth rate after a period of inanition was observed earlier in salamanders (Morgulis, 1911). These effects have been re-investigated by Jackson (1936, 1937). He finds that growth repression by under-feeding and by protein deficiency give somewhat different results. Whereas in the latter case the animals practically attain the control size after refeeding, in the former the final weight is significantly (16 per cent in the case of male rats) below the controls. In these experiments the rats were maintained at nearly constant weight for 15 weeks starting just after weaning. There was high mortality and the surviving rats showed, as before, the greatly accelerated growth rate when fully re-fed.

These results do not conflict with those presented in the preceding section (incomplete proteins, etc.). The difference is that here we are dealing with insufficient energy supply along with just sufficient food to maintain constant weight. The result is that some tissues grow at the expense of others and there is an increase in the total requirements which if not met results in starvation death. In the experiments with "incomplete" proteins or with amino-acids, the energy supply is evidently adequate, but one or more constituents essential to the formation of new protoplasm is lacking.

6. Maintenance and life span

The life span of organisms and isolated cells in relation to maintenance and growth may next be briefly considered. It is known that favorable environmental factors will prolong to some extent the life span of adult organisms. In the case of the unfertilized egg, which can be considered a resting cell, the life span can be extended by modifying the medium in which it lives. However, only under certain very special conditions is there any evidence for extremely prolonged survival of organisms and cells.

Certain animal organisms such as the branchiopod crustaceans (brine shrimps, water fleas, etc.) and the rotifers produce "winter eggs" which will survive for considerable periods. The seeds of many plants will survive for years. Spores of unicellular organisms are reported to last decades. Anthrax spores, for example, will survive 20 years. Certain non-sporing unicellular organisms will live "indefinitely" if they are rapidly dried. Even such relatively sensitive organisms as meningococcus and gonococcus remain alive and virulent for years under these conditions. Freezing will also keep certain bacteria and other organisms in a stationary viable state, particularly if the process is done rapidly so as to avoid the formation of ice crystals (see Luyet and Gehenio, 1940).

In these cases the systems exist in a relatively solid state in which diffusion processes are reduced to a minimum. The attainment of equilibrium conditions would therefore proceed at an extremely slow rate and it would require a very slight expenditure of energy to maintain the system for an extremely long period of time. Measurements that have been made on the metabolism of organisms under such conditions reveal either a very slight turnover or none at all.

A quite different kind of unlimited survival is evident in the results of tissue culture. The conditions for indefinite survival here involve growth of the tissue. The fibroblasts from the chick heart that have been kept alive since 1912 (Carrel, 1938) are continuously dividing and growing and so must be repeatedly subcultured. This kind of potential immortality of animal tissues was pointed out earlier by L. Loeb (1901) on the basis of long continued transplantation of mammalian tumors (see also Loeb, 1928). The indefinite survival in these cases is essentially the same as that exhibited by unicellular organisms that are repeatedly subcultured. The same sort of thing is illustrated in the case of the long-lived trees, such as the sequoia of California and the baobab of Cape Verde which have survived thousands of years. These organisms remain in the process of growth. Actually most of the tree is considered as dead.

The question as to whether tissues can be maintained outside the animal body for prolonged periods without growth has been examined by Parker (1936). He reports that certain embryonic and

adult tissues can be kept for several months in a functional state. It is this kind of survival which is of particular interest in connection with maintenance. With the exception of this work, it might appear that prolonged survival without growth is only possible by spore formation or some analogous change in state of the cells. The importance of further work along this line cannot be overemphasized, both as concerns the question of unlimited survival as well as the factors that maintain the state of differentiation of the tissues.

7. *Maintenance as a repair process*

One might consider maintenance as a sort of repair process. On this view it is assumed that there is a continuous disintegration of the protoplasm of the organism. When the building-up processes are sufficient to balance this, we have maintenance. When in excess, we have growth. This view, it would seem, makes the distinction between maintenance and growth a quantitative one. But some of the above evidence and some further considerations indicate qualitative differences. Studies on autolysis of tissues and organisms under sterile conditions (Haehn, 1936; Bradley, 1938) reveal a number of disintegrative changes, of which the hydrolysis of proteins to amino-acids is typical. This auto-digestion simply shows the ability of enzymes to catalyze a reaction in either direction. Now, on the basis of the law of mass action, the addition of any of these amino-acids would serve to displace the equilibrium to the protein side, and thus be effective in maintenance by counteracting the tendency towards hydrolysis of the proteins. For growth, however, all of the amino-acids characteristic of the particular proteins to be synthesized would be required, since the organism always builds up its own characteristic kind of protoplasm.

Some experiments of Voegtlin (1935) on autolyzing muscle, liver and tumor tissue are of interest in this connection. If the material is first kept for two or three hours in a nitrogen atmosphere, there is a rapid decrease in precipitable protein and an increase in amino-acid titre. Upon subsequent exposure for several hours to oxygen, resynthesis of protein occurs with a decrease in the amino-acid concentration. Presumably, although it was not demonstrated in this particular case, oxidations are proceeding under the aerobic conditions and this serves to displace the equilibrium towards the protein side.

Considering maintenance as a repair process is quite analagous to the generally accepted conception of the equilibrium state of a chemical reaction being that in which the rates of the forward and reverse reactions are equal. So in the maintenance of a living cell the hydrolysis of the proteins may be considered to be proceeding at a rate equal to their rate of synthesis. Where, as is evidently the case with most living cells, the equilibrium conditions are quite different from what would be thermodynamically defined for simple protein-amino acid systems, energy must be supplied to prevent true equilibrium from being attained. Also since most living cells are not isolated systems some of the components are free to diffuse into neighboring cells and into the surroundings of the organism. These components must then be continuously supplied. In cells that are relatively isolated from their environment, or that exist in a relatively dessicated condition, there is very little, if any, energy requirement. In the former case we must assume that the various protoplasmic components approximate conditions of true equilibrium. In the latter we assume that the rate of attainment of equilibrium is exceedingly slow.

One may expect, then, that the maintenance requirements of different kinds of cells will differ under constant external conditions, as will also the requirements for one kind of cell under different external conditions. In a developing embryo the wide variety of cells that are continuously arising will therefore continuously alter the conditions for maintenance, and this is probably one of the difficulties involved in experimentally blocking development (reversibly) at any stage. We may conclude, then, from the above considerations and the evidence available, that there is a distinct maintenance component in the metabolism of the developing embryo.

8. *Growth*

By growth is meant the conversion of food material into protoplasm. Unfortunately our concepts concerning protoplasm are extremely vague. It is generally recognized that a living cell contains a reserve of non-living material in addition to the "living substance". This reserve may be demonstrated, for example, in inanition experiments. We assume, here, that the material lost up to the point beyond which recovery is no longer possible is simply reserve, while the irreducible minimum remaining in the cell represents the protoplasm. This is admittedly a rather crude way

of regarding protoplasm. For growth studies on such material as unicellular organisms it is, in general, not necessary to distinguish between the protoplasm and the reserve material. The increase in number of cells (of uniform size distribution) may be taken as a direct measure of the synthesis of protoplasm.

In the case of the early development of a multicellular organism, this view of growth presents some practical difficulties. The eggs of most marine invertebrates, for example, absorb no material from the outside (with the exception of water, oxygen and perhaps some minerals) for a considerable period of their development. Here growth, in the sense of increase in mass, does not occur. However, we recognize certain constituents of the egg, such as the yolk, fat, some pigments, etc., as essentially nonprotoplasmic materials. It has been shown, in fact, that such materials can be removed to a large extent without incurring the death of the egg or loss of its ability to develop. During early development these "reserves" gradually disappear and growth in the sense of synthesis of protoplasm evidently occurs. In the case of the large eggs of oviparous animals, we encounter no particular practical difficulties in considering growth in this manner, since a region which is preponderately protoplasmic may be distinguished from one which is chiefly yolk. The embryo arises in the protoplasmic area, and its increase in size at the expense of the yolk is a measure of the conversion of food materials into protoplasm. In the case of oviparous animals with small eggs, the food material is distributed throughout the cytoplasm of the egg, and the embryo is not separated off from this reserve material. By adhering to the definition of growth as synthesis of protoplasm, we evidently introduce difficulties in its experimental determination in the early development of eggs of this type. But this seems preferable to using the evidently fallacious notion that no growth is occurring where there is no increase in mass. One would not think of assuming that a hen's egg, for example, is not growing because there is no increase in total mass up to the time of hatching. Here, of course, we can recognize the embryo as distinct from the yolk at an early stage. To be consistent, then, we must assume that growth occurs in the early development of the small eggs of oviparous animals. The difficulties in quantitative estimation may be compensated by the possibility of utilizing when necessary the general results of growth studies on various kinds of living things.

9. Storage

Following this line of thought it is also apparent that we must consider a process, called storage, as distinct from growth. This process would represent the accumulation by the cell of reserve food materials. The tremendous enlargement of the young oöcyte as it is transformed into the ripe egg may be considered as being due principally to storage. This process is exhibited particularly in the later stages of development; for example, in the development of the ovary, or in the development of such structures as the fat bodies of insect larvae which are used up during pupation and metamorphosis. Storage may be regarded as a component of the processes of differentiation. But this depends on how differentiation is to be defined.

10. Growth without differentiation

We may consider first some cases illustrating the separateness of growth and differentiation. There is, of course, no point in considering growth without maintenance, since the former *ipso facto* implies the latter. We are interested to know whether at any stage of development growth and differentiation can be dissociated.

An excellent example of growth without differentiation is that of the anidian chick eggs (Dareste, 1882; Grodzinski, 1934). The anidian blastoderm grows considerably with no sign of differentiation. In this example differentiation fails completely to occur right from the start of development. For later stages of development, growth without differentiation may be illustrated by the classical experiments on removing the thyroid of frog tadpoles (Allen, 1916, 1938). As is well known, the animals fail to metamorphose but continue to grow at about the normal rate and attain dimensions beyond the metamorphosis size. There are similar examples in other animals. In insects, Wigglesworth (1936) has shown that implantation of the corpus allatum from third or fourth stage nymphs of *Rhodnius* into fifth stage nymphs would prevent metamorphosis which normally occurs at this stage. The growth and moulting continues, giving a sixth and even a seventh nymphal stage. The corpus allatum seems to restrain differentiation towards the adult form.

Metamorphosis might be considered a special case in that we are dealing with the transition of one kind of fully functional (except generally for reproductive faculties) self-sustaining organism into another form. We might inquire, then, whether before metamorphosis or in the development of a non-metamorphosing species differentiation may be interrupted at any stage without affecting growth.

A difficulty in accomplishing this is apparent in embryos that derive the material for growth from an external source. Suppose, for example, a chick embryo is to be kept in the one somite stage while enlarging to the size attained at hatching. The lack of a proper blood circulation would render the food material unavailable except to those cells adjacent to the yolk. Also oxygen would become unavailable to the internally situated cells as the embryo enlarged. From dimensional considerations this difficulty does not appear avoidable; only abnormal growth or the anarchistic type of growth described by Byerly (1926) seems possible in such a situation.

In embryos that contain the material for growth internally, the difficulty is in recognizing growth as here defined. Suppose, for example, differentiation of a salamander embryo were blocked in the gastrula stage. Continuance of growth would mean increase in the protoplasmic substances (specific proteins, etc.) characteristic of that particular stage, at the expense of the contained yolk materials. Information of this sort is not generally available. It seems reasonable, however, to assume that if cell division continues, in spite of the block to differentiation, protoplasmic synthesis goes on. Using this as a criterion for growth we shall examine some cases of suppressed differentiation.

In salamander embryos it has been shown (Durken, 1935) that ultraviolet radiation of the dorsal lip of the blastopore at the gastrula stage inhibits differentiation, presumably due to inactivation of the organizer. Gastrulation is completed but the neurula stage is not attained. Cell division evidently continues but data are not given from which to decide whether it proceeds beyond the point characteristic of the particular stage.

Interference with the differentiation of specific parts of the embryo without particular injurious effects can be obtained by chemical means (see review of Lehmann, 1937a). The various examples, however, do not illustrate suppression of differentiation but rather alteration of the type of differentiation. Thus in the classical case of the lithium larvae of sea-urchins (Herbst, 1893; Runnström, 1928) there is a conversion of presumptive ectoderm into endoderm. In the case of the "chorda-lose" salamander embryos (Lehmann, 1937b) the presumptive notochord cells become mesodermal somite cells.

In the numerous defect experiments with which experimental embryology abounds, one might expect to find illustrations of suppressed differentiation. But again it appears in general that altered differentiation results. In the well-known experiment of Lewis (1902–03), for example, extirpation of the optic vesicle results in failure of lens development, but the presumptive lens cells apparently do not remain in the state of differentiation characteristic of the stage of operation but develop into typical ciliated (?) epidermal cells.

Explantation experiments should, it would seem, supply good examples of the failure of parts to differentiate. This type of experiment is the reverse of the defect experiment. In the latter, particular inductors are removed, but inductive action of other parts of the embryo may influence the result; in the former particular parts are removed but inductive action of the culture medium may influence the result. The explantation (interplantation) experiments in amphibia in which parts are transferred to the eye-cavity (Durkin, 1926; Bautzman, 1929; Kusche, 1929), the body cavity or lymph spaces (Holtfreter, 1929) illustrate such action; a wide variety of tissues developing from the isolated parts. In the more recent experiments of explanting in a neutral salt solution (Holtfreter, 1931, 1933a) the effect of the medium is presumably eliminated. Presumptive medullary plate of the early gastrula cultured in this way forms an irregular mass of atypical epidermal cells, just as does the presumptive epidermis. The few exceptional cases in which some nervous tissue did develop are explained as coming from older embryos. In exogastrulae (Holtfreter, 1933b) failure of the ectoderm to form nervous tissue is also shown. Both in the explants and in the exogastrulae, contact of the ectoderm with an inductor (e.g. chorda-mesoderm) results in the differentiation of neural structures. If the isolated ectoderm were capable, after being cultured for some time, of reacting to inductors we would be justified in assuming that no

differentiation had occurred while growth, as evidenced by mitosis, continued. But according to Holtfreter (1938, p. 301) the ability of the ectoderm to react decreases with increased time of culturing. The change corresponds roughly to that undergone by the presumptive epidermis in the embryo itself. Thus, at best, we have here only a partial dissociation of growth and differentiation.

A highly interesting example showing independence of growth and differentiation is found in the viviparous medusa, *Chrysaora hysocella* (Teissier, 1929). While the eggs of this animal are all of the same size, the blastulae, gastrulae and planulae are extremely variable. One can find in the same animal planulae that are smaller than many of the gastrulae and gastrulae that are smaller than many of the blastulae. This may be due either to differences in the rate of growth of different eggs, or to differences in the rate of differentiation, or both. In any event it shows that a considerable amount of growth may be obtained without differentiation. Thus planulae may be obtained that vary as much as 300 to 1 in volume, the smallest planulae having only three or four times the volume of the egg. The increase in mass of the embryos is due, of course, to parental nourishment and starts evidently in the blastula stage. Teissier showed that blastulae of radically different size have cells of exactly the same dimensions. Therefore, increase in number of cells parallels the increase in size. Cell division would in this case be an index of growth. Whether it could be generally used as a criterion of growth (as we have defined growth) might possibly be determined on an egg of this type, especially since in the early segmentation stages there is no increase in mass.

A somewhat analagous case is given by the giant and dwarf races of rabbits (Castle and Gregory, 1931). The giant (Flemish) and the dwarf (Polish) races both produce eggs of the same size. The eggs of the former, however, divide much more rapidly, and at identical stages of differentiation the embryos of the larger species are larger. Cell size is the same in both species. This case illustrates an acceleration of growth with a constant rate of differentiation.

We cannot discuss here the numerous cases of genetic size differences in animals that have been studied. But it should be noted that larger size may be attained by prolongation of the growth period as well as by increase in rate of growth.

From the evidence presented and many similar cases that may be found in the literature, it appears that growth without differentiation can occur in embryonic development. The reservation must be made, however, that this has not been demonstrated for very many different stages of development. But this incompleteness may be due to the lack of experiments designed to test this point in particular.

11. Differentiation

The preceding account implies a definition of differentiation as simply those processes not included under what we regard as growth and maintenance. We may then include under differentiation (a) the various form changes (morphogenetic and histogenetic changes) that occur in development, and also (b) the production of the substances characteristic of the various tissues. (a) One may, as is often done, consider the form changes as "directed" growth. D'Arcy W. Thompson (1917), for example, states that "the form of an animal is determined by its specific rate of growth in various directions." This involves a somewhat different definition of growth than here employed. Also, it seems preferable not to use the term growth in this connection unless it is shown that it is impossible for the form changes to occur without increase in protoplasm.

(b) The production of substances characteristic of the various tissues would be included under growth where the particular substances occur in self-multiplicative (self-perpetuating) structures, such as the nucleus, central bodies, mitochondria, etc. It would be included under differentiation in the case of structures that are not self-multiplicative as the fibrillae of various sorts, the cilia, specific granulations, etc. In general it is these non-self-multiplicative structures that characterize the various tissues. This distinction would be valueless if non-self-multiplicative structures were formed only during increase in self-multiplicative structures; that is, during active cell division. Actually, however, the reverse is more generally true; for, as recent evidence from tissue culture work and other sources shows, the visible cellular differentiations appear when cell division has ceased. This will be discussed below.

Although growth can apparently occur without differentiation, it does not follow that the reverse must be true. In discussing this question we must distinguish between what may be termed concomitant growth and antecedent growth.

12. Histogenetic changes

That the visible histogenetic differentiations occur without concomitant growth is evident for most of the tissues of the body, provided that we accept the absence of cell division as a criterion for the absence of growth. The tissue culture work of recent years (see review of Bloom, 1937) shows, in fact, that there is a sort of antagonism between cellular differentiation and growth. Thus actively dividing cells remain "undifferentiated." The cells differentiate only when culture conditions are such that multiplication is inhibited (e.g. delayed growth method of Fischer and Parker). In a recent survey Dawson (1937) points out that contrary to the general view, mitosis may occur in partially or fully differentiated cells without regression of cytoplasmic structures. If increase in the non-self-multiplicative structures occurred simultaneously this would mean an overlapping of cellular differentiation and growth, as we have defined them. Dawson, however, states "The general conclusions of Berrill and Huskins (1936) that there is considerable evidence that cell structures and form can only be developed during the interkinetic phase of the nucleus is probably justified. . . ." It is also well known that in tissue culture, most types of cells transform into fibroblast-like cells or "indifferent" epithelial cells and proliferate as such. We may conclude, then, that cellular differentiation is not only separable from, but generally occurs without concomitant growth, assuming, as before, that mitosis is an index of growth.

The question as to whether cellular differentiation can occur without antecedent growth implies that we have a starting point of zero growth. However, if we exclude the miracle of spontaneous generation, all living cells must have a previous growth history. One might, though, with some justification assume that a ripe unfertilized egg represents the endpoint of one stage of growth and the starting point of another. The same then must be assumed for any cell of the body that has ceased growing (i.e. dividing). The question then is whether such cells (ripe eggs, muscle cells, nerve cells, etc.) can transform into another type without the occurrence of growth. That is, can a cell lose its specific differentiations and elaborate structures characteristic of another type of tissue without going through a growth phase?

The nearest thing to this is perhaps the case described as differentiation without cleavage (Lillie, 1902). Eggs of the marine annelid *Chaetopterus* were found after treatment with KCl to develop into ciliated trochophore-like structures without having undergone segmentation. But although cytoplasmic division failed to occur nuclear division quite evidently took place resulting in a large number of nuclei or a single large nucleus being present in these atypical larvae. It also has been shown that during the development of such larvae the respiration rises although more slowly than normal (Brachet, 1938; Tyler and Horowitz, 1938) and that there is a synthesis of thymonucleic acid. Growth then in the sense we have been using the term, namely, synthesis of protoplasm, evidently occurs and this case can not be used as an illustration of differentiation without antecedent growth. It does, however, demonstrate strikingly the extent to which the appearance of certain structures and assumption of a definite form is independent of the actual subdivision into separate cells.

13. Morphogenetic changes

We may next consider whether the form changes (morphogenetic changes) can occur independently of growth. If by independent of growth is meant complete absence of antecedent as well as concomitant growth, then evidence on this point is completely lacking with the exception of the case of "differentiation without cleavage," discussed above. Considering only concomitant growth, we know of no cases of the form changes occurring in its absence. In fact, it is generally thought that the morphogenetic changes are directly the result of growth in specific directions, although the term growth is not always used in the same way.

On the assumption that cell division is an index of growth the question is whether a particular form change can occur in the absence of concomitant cell division. Observational evidence on mitotic indices (see recent work of Richards, 1935, for earlier references) of developing embryos tend to show an acceleration of cell division in parts that are undergoing marked form changes. This, however, does not necessarily mean that a particular form change results from increased cell division. The reverse might very well be true or both might result from some common factor. The inadequacy of simply increased mitosis as a causative factor may be illustrated by considering such a form change as gastrulation in an echinoderm blastula. Here, since there is practically no intake of material (except possibly water and some salts) from

the outside there is no increase in mass. Consequently increased cell division in the invaginating region would simply produce smaller cells. But the presence of smaller cells in part of the blastula wall does not necessitate inturning since in the sea-urchin egg by an unequal fourth cleavage there are smaller cells at the antipole during the entire blastula stage. Also removal of these micromeres does not prevent gastrulation (Horstadius, 1928). It is interesting to note too that the only available observations (Schmidt, 1904) show no differences in the rate of cell division in the different regions of the sea-urchin embryo during gastrulation.

It would, of course, be extremely important to determine whether a particular form change such as gastrulation, neurulation, etc., could occur without the normally accompanying cell division. Since such evidence as exists indicates the opposite it may be concluded for the present that morphogenesis is intimately tied up with growth. This does not contradict the previously discussed independence of cellular differentiation and growth, since, as Ranzi (1929, 1931) and others have shown, the histogenetic changes are to a large extent independent of the form changes.

14. Differential effects on the rates of growth and differentiation

In the preceding section it was pointed out that there is no evidence of the morphogenetic changes occurring without any growth. There is, however, evidence showing that the rate of differentiation may be accelerated with respect to growth. The precocious metamorphosis that resulted from feeding thyroid to frog tadpoles is considered by Gudernatsch (1912, 1929) as demonstrating differentiation without growth. Actually growth, as we use the term, very likely occurs during metamorphosis, the material being supplied by the resorption of certain parts. More strictly, the thyroid feeding advances the time of onset of the metamorphic change. The transformation itself is apparently not speeded up. Whether this, then, should be regarded as an acceleration of differentiation is a debatable question. Certainly there is no evidence that the early stages in the development of the tadpole are speeded up by thyroxine treatment, or by any other agent inducing precocious metamorphosis. As was pointed out in a preceding section it would be better to consider examples from non-metamorphosing forms or in stages of development not including metamorphosis.

A question that arises in connection with the work on metamorphosis is how far the time of onset may be advanced. The evidence shows that very young frog tadpoles may be made to metamorphose, but even the youngest of these are still "fully" developed tadpoles. There is normally, prior to metamorphosis, a considerable period during which growth without any marked form changes occurs, although such cellular differentiation goes on as must accompany the increase in size of the various organs. It would be of interest to know whether metamorphosis can be made to occur before this period. Advancing it sufficiently far would, of course, amount to eliminating it altogether. We would then have direct development from egg to frog, which does in fact normally occur in certain species of amphibia (see Noble, 1931).

Some experiments on chick embryos illustrate a differential acceleration of differentiation with respect to growth. Hoadley (1929) found by transplanting embryonic parts to the chorio-allantoic membrane that the organs which developed were much smaller than those of the intact embryo at comparable stages of differentiation. This was examined particularly in the case of the spinal cord, the mesonephros and the eye. The size of the organ is smaller the earlier the stage at which the transplant is made. Thus, the eye that developed from a transplant from a 20-hour chick was about $\frac{1}{70}$ of the control size while that from a 48-hour chick was $\frac{1}{3}$. Cell size was observed to be the same in the grafts as in the controls. There are, then, fewer cells present in the graft, so cell division was quite evidently retarded. Similarly, Waddington (1932) found that when whole blastoderms are cultivated in vitro, the embryos that develop are much too small for their stage of differentiation. The rate of differentiation was slowed up in comparison with the intact embryo but the rate of growth was retarded considerably more. The previously mentioned rule of an antagonism in tissue culture between growth and cellular differentiation perhaps accounts for these results. But there is also in these two cases a relative acceleration of the form changes as well. So the morphogenetic changes too are to some extent independent of growth.

15. Brief Summary

We have attempted in the preceding pages to define the fundamental processes that are generally

assumed in development and examined some naturally occurring and some experimentally produced cases in which the integration of these processes appears to be altered. We may summarize the discussion briefly as follows: (1) there is good evidence for maintenance occurring without growth and differentiation. (2) Maintenance and growth may occur without differentiation. (3) Cellular differentiation occurs without growth. (4) There is no evidence as yet that the form changes can occur without growth but the rates can evidently be differentially altered.

The evidence affords for the present sufficient justification for distinguishing between these conceptually different processes in development.

III. EVIDENCE OF ENERGY REQUIREMENTS

1. 'A priori' considerations

The processes of differentiation are what characterize the developing embryo in comparison with the adult organism or with a tissue culture of actively growing cells. We are therefore interested in determining the energy requirements for the differentiation processes apart from that for the normally accompanying maintenance and growth processes. This could be rather simply done if the requirements for the maintenance component in the developing embryo were the same as in the adult per unit mass, and that for the growth component the same as in the "fully formed" young. But as was pointed out above this is very likely not the case. In fact different cells of the same organism undoubtedly have different maintenance requirements. It is necessary, then, to approach this problem in some indirect manner. There is, for example, the possibility of utilizing experiments and normally occurring situations such as we have described above, in which the differentiation, growth, or both processes are eliminated in the developing embryo. Very little work has been done along this line. Another possibility is to vary the energy requirements for one of these processes while that for the others is unaltered, or, what is very similar, cases in which the rates are differentially altered could be utilized.

It is, in the first place, important to determine whether energy is actually required for differentiation. It has often been stated, principally on the basis of Meyerhof's (1911) and Shearer's (1922) experiments, that no energy is required. Meyerhof's and Shearer's experiments showed that in sea-urchin embryos the ratio of heat produced to oxygen consumed was constant throughout development. It was assumed, then, that if energy were required for differentiation, there should be a decrease in the heat evolved per mole of oxygen consumed at times when work was actively being performed. There are several objections that may be raised against this point of view. It may suffice to point out that the heat produced carries no identification of its past history in the embryo. A good part of the energy represented by the heat evolved may very well have been used in producing the form changes before it appeared as heat. What those experiments do show, at least for the limited number of stages examined and within the limits of accuracy of the measurements, is that, if energy is required, it is not stored up in the embryo but appears as heat. This would mean that the form changes in development are of the plastic rather than the elastic type.

In the chick embryo there appears to be the possibility that a small percentage of the energy is stored up in the structure, for Bohr and Hasselbalch (1903) found that there was 4 per cent less heat production than should be obtained from the oxygen consumed and the CO_2 evolved. This may be due, as Needham (1931, p. 964) points out, to experimental error.

If energy is stored up in the structure, it might conceivably reside in the increased surface area. Some calculations of Ellis (1933) and Borsook (1935) show that this would be an extremely small fraction of the energy turnover. Using the value for the surface tension of a water-air interface (72.75 dynes/cm.), which is considerably higher than the values Harvey (1931) and Cole (1932) obtained for the tensions at the surface of marine eggs, they point out that the 4 per cent "organization energy" (3480 calories) of the chick embryo would provide for an increase of 2×10^9 sq. cm. But a chick embryo of 50 c.c. volume and with cells that they assume to average one-tenth the volume of a human red blood cell would have a total cell surface of 2.4×10^5 sq. cm., which is 0.1 per cent of what the doubtful organization energy would provide. These calculations leave out of account entirely the increase in intracellular surface, but it is hardly possible even to guess the magnitudes involved. There is, however, not much point to such calculations unless we can conceive of some way of recovering the supposedly stored up energy. This certainly could not be

done by cytolysis, for example, since what is required is a return to the initial state. A true reversal of development would be necessary in order to settle this question.

We know at present of one instance in which reversal has been obtained but this covers only a very restricted initial period in development. This case is a reversal of fertilization (Tyler and Schultz, 1932) obtained by treating eggs of the echiuroid worm, *Urechis*, with acidified sea water within a short time (3 minutes) after insemination. The eggs are caused to return to their initial unfertilized state, although the spermatozoön is not expelled but remains in the egg. That the eggs have actually been reversed is shown by the fact that they can be re-fertilized; they then develop as dispermic eggs. During the reversible period the egg undergoes a change in shape from an indented sphere to a practically perfect sphere, whereby there is a decrease in surface area. The return to the unfertilized condition involves a reversal of this change in shape. We might expect that the decrease in surface area would involve a liberation of energy, and the return to the original condition an absorption of energy. But this would be extremely difficult to demonstrate for the short time interval of the change, especially since the values might be very small in comparison with the total energy turnover. If other and longer periods of development could be reversed we would be in a position to answer not only the question of storage of energy in embryonic structure but also many important problems of development.

The question as to whether or not there is an energy requirement for differentiation does not rest on showing that energy is stored up. In discussing this question we must consider separately the mechanical changes and the chemical changes of differentiation. These correspond respectively to the form changes and to cellular differentiation, although in using these terms it must be kept in mind that the latter involves mechanical changes in the form of the cell and the former must have chemical transformations as a basis (Huxley's "chemo-differentiation").

2. *The chemical changes*

When we speak of the energy requirement for a particular chemical change we mean the total energy that must be supplied in order for the reaction to occur. Reactions that proceed spontaneously evidently require no energy. To decide, then, whether or not the production of the particular substances characteristic of the various tissues requires energy, one would have to determine whether the reactions would proceed spontaneously from the precursors in the concentrations present in the cells. Data on this are lacking, however, in many respects. Not very many of the characteristic tissue substances are known in pure form, and, where the substances and their concentrations and state in the cell are known, the precursors are not. Even the origin of a substance as well known as haemoglobin is obscure. Determinations of equilibrium constants or of the free energies from which the constants could be obtained can hardly be made if the reactions cannot be precisely formulated.

Let us, however, consider the situation in a general way, without distinguishing particularly between cellular differentiation and growth. In the hen's egg it appears that the raw materials are not very different from the materials of the embryo itself (see Needham, 1931, p. 1062). The processes of cellular differentiation and of growth involve the transportation of the raw materials from the yolk to the cells of the embryo. For those raw materials, such as proteins, which are present in the form of large molecules, breakdown into smaller entities (polypeptides or amino-acids) is evidently necessary before they can be absorbed by the cells. We need not consider, at this point, whether or not this breakdown proceeds spontaneously, i.e. with a decrease in free energy. Let us assume that the materials of the embryo have about the same free energy content as the raw materials (which seems reasonable on the basis of the above-mentioned similarity between embryo and yolk materials). If, then, the breakdown processes involve a decrease in free energy the synthetic process will involve an increase and vice versa. Since the sites of breakdown and synthesis are far removed from one another, it is evident that energy liberated by one of the processes is not likely to be utilized by the other. It may be concluded, then, that the overall process of converting the raw materials into embryonic materials (representing both growth and cellular differentiation) very likely requires energy in eggs such as that of the chick. We shall not discuss here the question as to the amounts stored and dissipated, nor the relation to energy supplying mechanisms, coupled reactions, respiration and fermentation.

In eggs of viviparous animals such as mammals, the raw materials are evidently supplied in the form

of smaller entities, the breakdown processes having occurred in the maternal organism. Here, then, it would be necessary to decide whether the synthetic processes require energy. For the synthesis of proteins from amino acids there is no data as to the energy relations. For the synthesis of dipeptides from amino acids in dilute solution energy must be supplied, as recent free energy data show (Huffman, Ellis and Fox, 1936). If, as appears likely, protein synthesis proceeds over this path, and if other synthetic reactions are analagous, we may conclude that the chemical changes of cellular differentiation and growth probably also require energy in this type of egg.

In the small holoblastic eggs of oviparous animals the raw materials are contained intracellularly and there is no evidence that they must be broken down, transported and resynthesized into the materials of the embryo. It is entirely possible that very little change is required to form the materials of the embryo or that the change involves only the breakdown reactions (probably but not necessarily attended by a decrease in free energy) or that energy liberated in breakdown is utilized in synthesis, etc. It would be important then to determine the kinds of chemical changes occurring in this type of egg. From the information available it cannot be decided whether, for example, there is a synthesis of protein from amino-acid during development. If such synthetic processes occur the situation would be analogous to that in eggs of viviparous animals.

In regard to the energy cost of cellular differentiation there is not very much that can as yet be said. The heat production and respiration of developing embryos has, of course, now been determined in a large number of animals (see Needham, 1931, part III, section 4). But as we have seen the values may be attributable to maintenance, growth and the form changes as well as the chemical changes of differentiation. It would be necessary to know the values of the chemical work performed and the free energy change in the energy-supplying reaction in order to state the efficiency. This would be simply the ratio of the former to the latter. The usual methods of determining free energies involves measurements of chemical equilibrium or electrode potentials on well-defined systems. In recent years application of the third law of thermodynamics has led to the determination of free energies by calorimetric measurements of entropies and heat contents (see Parks and Huffman, 1932 for application to organic compounds), and this appears to be the most promising method for dealing with substances involved in biological systems.

3. *The mechanical changes*

For an elastic type of body, the energy required (per unit volume) to produce a given form change characterized by a definite amount of shear, s, would be

$$E = \int_0^s f\,ds \qquad (1)$$

in which f is the applied force (or shearing stress) and is a function of s. Where Hooke's law, $f = Gs$, holds, then

$$E = \tfrac{1}{2} G s^2 \qquad (2)$$

in which G is the shear modulus. For elastic deformations other than simple shear, other parameters would have to be introduced. This energy would, of course, be stored up as elastic potential energy, recoverable as work or heat upon reversal of the form change.

For a fluid type of body the energy required (per unit volume) would again be given by (1). But since here f depends on the rate of shear, $(D = \frac{ds}{dt})$, we may substitute Ddt for ds and

$$E = \int_0^t f\,Ddt \qquad (3)$$

In ordinary (Newtonian) liquids

$$f = \eta D \qquad (4)$$

in which η is the coefficient of viscosity (or of internal friction) then

$$E = \eta D^2 t \qquad (5)$$

This energy would be dissipated immediately as heat and the form change can only be reversed by further expenditure of energy.

Actually the embryo exhibits properties of both elastic and fluid bodies. If it is rapidly compressed and released or stretched and released, it returns to its original shape. But upon prolonged deformation the return is inhibited. Such behavior is characteristic of what are termed plastic bodies. The deformation of a plastic body may be treated in the same way as that of an elastic body with the introduction of a term for what is called relaxation.

Also it might be treated as a fluid body with a certain yield value of the applied force below which no flow occurs. Relaxation effects a decrease in internal stress of the deformed body with time. Assuming simply that in the interval of time, dt, the stress decreases in intensity by dt/R, in which R is a relaxation time constant, we have

$$df = -\frac{f}{R}dt \qquad (6)$$

The decrease in internal stress ($-df$) under a constant applied force results in further deformation (increase in amount of shear, s), that is

$$-df = G\,ds \qquad (7)$$

and substituting this in (6) we have

$$Gds = \frac{f}{R}dt \qquad \text{or} \qquad f = GR\frac{ds}{dt} \qquad (8)$$

Writing D, the rate of shear for ds/dt brings out the similarity of this equation to equation (4). In place of the viscosity coefficient, η, there is here the product of the shear modulus, G, and the relaxation time, R. The behavior, then, is that of a liquid with a viscosity equal to GR.

This brief treatment of elastic, fluid and plastic bodies is presented here merely to illustrate the kind of information that is required. Even with homogeneous substances the situation is much more complicated than is represented here (see Love, 1927; Houwink, 1937, or other treatises on elasticity and plasticity). In a heterogeneous system, such as an embryo, with a number of structural elements of different types, the deformation will be controlled by a large number of parameters and the relations would be extremely complex. Possibly some relatively simple measurements of viscosity or of elastic moduli and relaxation or of some other properties might enable us to determine the energy required for a particular form change. At present such direct determination does not seem feasible.

A few words may be said concerning the justification for assuming that the form changes of a developing embryo are of the plastic type. If an embryo is killed by heat or radiation or chemical agents it retains its form. The objection might be raised that the process of killing has altered the material in such a way that elastic stresses are relieved. In that case heat would be expected to be produced equivalent to the loss in elastic potential energy. While no information is available on the "death heat production" of embryos, measurements on yeast and on erythrocytes (Lepeschkin, 1937) show no very appreciable effect. Also the killing process might just as conceivably allow elastic recovery to occur if the system were one exhibiting "blocked elastic deformation." For example in resins (Houwink, 1934) an increase in temperature is required for recovery to proceed to completion after deformation and similarly in wool (Astbury, 1933) treatment with a chemical agent.

If instead of killing the embryo the energy supplying systems are blocked the form is likewise retained. This may be done by such agents as cyanide, anaerobiosis, iodoacetate, fluoride, etc., which act on the respiratory or fermentation mechanisms. It is possible, however, that other systems take over the energy supplying job in such cases. Other reasons for considering the form changes to be of the plastic type are the failure of recovery of original form after prolonged application of an external force and the constancy of the calorific quotient, mentioned above.

4. *The principle of similitude*

It has been possible, by indirect means, to demonstrate an energy requirement for differentiation and to elucidate certain problems of development (Tyler 1933–38). This work involves the employment of what is known as the principle of similitude or dimensional analysis. A systematic treatment of the methods of dimensional analysis is given by P. W. Bridgman (1931). Briefer accounts and applications are given by Rayleigh (1896, p. 429 *et seq.*, 1915), Kelvin and Tait (1903, p. 300 *et seq.*), Tolman (1914), Buckingham (1915, 1921) and the *Dictionary of Applied Physics* (1922, vol. I, p. 81 *et seq.*).

We need not, then, go into the details of the method here. The essential features of the principle are that the dimensional formulas of all quantities dealt with in formulating natural laws are expressible as products of powers of the fundamental quantities and that all terms in any equation having a physical significance must have identical dimensions. Tolman (1914) considers the basic postulate as a relativity principle and states it as follows: "The fundamental entities out of which the physical universe is constructed are of such a nature that from them a miniature universe could be constructed exactly similar in every respect to the present universe."

The principle serves not only as a check on any

formula derived either on experimental or theoretical grounds, but can be turned to advantage by providing *a priori* information regarding the forms which the results of any investigation ought to take. It is extremely useful in the preliminary analysis of any proposed problem. It is most extensively employed in model experiments, such as are made in aeronautics, in which it is desired to predict the behavior of a full scale machine or part from measurements made on a small scale model.

According to Pütter (1911), Galileo was evidently the first to employ the general principle for living as well as non-living structures. He showed that there must be a limit to the size of building or animal that could be constructed if the relative proportions of the structure and the kinds of building materials were unaltered. This follows from the difference in the way in which the structural strength and the weight vary with the dimensions. The former increases with the square of a linear dimension, the latter with the cube, so that there is a limit beyond which the structure collapses under its own weight.

Spencer (1898, p. 155) employed this principle in discussing the sizes attained by various animals in relation to their habitat. He plausibly accounts, for example, for the fact that the Condor, which is the largest bird that can fly, weighs only 30 to 40 lb. and that no land animal of the size of the whale exists. Pütter (1911, p. 884 *et seq.*) and D'Arcy W. Thompson (1915, 1916) made extensive use of the principle of similitude in discussions of the growth, the speed, the shape and the metabolism of animals. A recent application of this dimensional reasoning was made by Langmuir (1938) in showing that the often cited figures of 600 to 700 miles per hour for the speed of the deer-fly are not possible. At such speed of flight this insect would have to consume its own weight of food every second, assuming that it has about the same thermodynamic fuel efficiency as man. A more reasonable speed comes out to be about 25 miles per hour.

These examples are presented here simply as illustrations of some applications that have been made of the principle of similitude. The work on dwarf embryos, which will next be discussed, represents, I believe, the first attempt to apply the principle to a biological problem of experimental nature.

5. *Dwarf embryos*

To determine whether or not there is an energy requirement for differentiation it would, as we have already suggested, be advantageous to produce embryos in which we might expect the requirements for differentiation to be altered without affecting growth and maintenance. It appeared (Tyler, 1933) that these conditions might be satisfied by dwarf embryos, such as Driesch (1891) first showed can be obtained by separation of the two cells of the two-cell stage of the sea-urchin egg. Since the amount of living material and also the rate of subsequent cleavage are unaltered by separation of the two cells, the two dwarf embryos should have the same maintenance and growth requirements as one whole embryo. The requirements for the form changes of differentiation, however, should be greater in the case of the two dwarf embryos. To show this we make use of the principle of similitude. We wish to determine the ratio of the energy required (work done) in the normal (full-sized) embryo to that in the dwarf embryo when both undergo similar changes in shape. The change in shape that we shall consider is that of gastrulation which is essentially the indentation (invagination) of a hollow sphere, but the results should apply to most of the other form changes that the embryo undergoes.

The dwarf embryo is a small model of the normal embryo. It is not, however, a perfect model. Driesch's (1891, 1900) and Morgan's (1895, 1903) measurements on the dwarf embryos of the sea-urchin showed that, in the blastula and gastrula stages, the surface area (not the volume, as is often supposed) is one half of that of the normal embryo; also that at gastrulation the cells of the dwarf are of normal size, but one-half the normal number. The blastula wall at the time of gastrulation is then of the same thickness in the dwarf as in the normal embryo, which means that it is too thick in proportion to the size of the dwarf.

The relations of the dimensions of the dwarf and normal blastulae are illustrated in Fig. 1. Since the surface area of the dwarf is one-half the normal, then if D is the normal diameter that of the dwarf is $D/\sqrt{2}$. If the dwarf were geometrically similar to the normal its wall thickness should likewise be $d/\sqrt{2}$, where d is the normal wall thickness. A hypothetical dwarf of this wall thickness is illustrated in Fig. 1b. The actual dwarf blastula, of wall thickness d, is represented by Fig. 1c.

We must compare first the normal embryo (Fig. 1a) with the geometrically similar hypothetical dwarf (Fig. 1b). If the production of a deformation characterized by the depth of invagination a

requires the force F in the normal embryo, then by the principle of similitude the similar deformation, $a/\sqrt{2}$, in the hypothetical dwarf will require the force $F/\sqrt{2}$. The work done, or energy required, in the hypothetical dwarf will be one-half that in the normal embryo. Now in proceeding from the hypothetical dwarf of wall thickness $d/\sqrt{2}$ to the actual dwarf (Fig. 1c) of the original wall thickness d, it is evident that the latter will require a greater force than will the former in order to give a deformation characterized by $a/\sqrt{2}$ in both cases. Just how much greater this force must be will depend on the way in which the force varies with the wall thickness. If we assume that it varies linearly with the first power, then, where F_d is the force required by the actual dwarf,

$$\frac{F_d}{\frac{F}{\sqrt{2}}} = \frac{d}{\frac{d}{\sqrt{2}}}$$

and $F_d = F$. The work done or energy required in producing the deformation $a/\sqrt{2}$ in the dwarf will then be $W/\sqrt{2}$, where W represents the energy required to produce the deformation a in the normal embryo. Two dwarf embryos will then have the energy requirement $W\sqrt{2}$; that is, 1.41 times that of one normal embryo. The actual figures may very likely be quite different depending for one thing on how the forces vary with the wall thickness, the solution of which is not readily obtained for a hollow sphere. In any event it is evident that there will be a considerable increase in force required in going from the hypothetical dwarf to the actual dwarf.

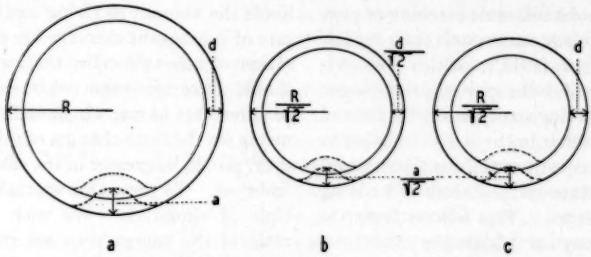

FIG. 1. DIAGRAM SHOWING THE RELATIVE DIMENSIONS AT THE TIME OF GASTRULATION
a, normal embryo; *b*, hypothetical, geometrically similar dwarf embryo; *c*, actual dwarf embryo from an isolated blastomere of the two cell stage. See text for further details.

The expectation, then, is that for corresponding form changes there should be a greater energy requirement in the case of two dwarf embryos than in the case of one normal embryo. On the simplest assumption this increase should amount to 41 per cent. This conclusion was tested experimentally by measurements of the respiration and rate of development of dwarf and normal embryos.

(To be concluded)

CONTRIBUTIONS TO THE PHYSIOLOGY OF FORM GENERATION IN THE DEVELOPMENT OF THE SEA URCHIN

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ALMOST all of our knowledge about the physiology of form generation in ontogeny has been achieved by studies on the eggs of the amphibians and the sea urchin. Although the development of these objects shows certain general features, probably due to common processes in the generation of form, they differ in other essential points. Thus Needham in a review of developmental physiology points out: "Instead of primary and secondary organisers, workers on echinoderm development prefer to speak of a double gradient system. . . ." It therefore seems necessary to the author to give a short survey of the development of this gradient hypothesis and the facts on which it is based.

The first conception of a gradient as put forward by Boveri in 1901, was based upon the differentiation of isolated fragments. Besides morphogenetic criteria for gradients, criteria based on considerations of physiological observations and protoplasmic structure have been put forward. Thus certain regions differ in some respects: (1) sensibility to destroying agents (Child, 1916; Runnström, 1925, 1928); (2) changes in the tendency of the embryonal regions to differentiate after suitable chemical treatment (Runnström, 1928; Lindahl, 1936); (3) distribution of potencies and capability of induction (Hörstadius, 1935). (The term "induction" here used by Hörstadius has a wider meaning than that used for amphibia.) It is a striking fact that all these qualities are graded with a distinct continuity. If we, for instance, speak about a "vegetative organiser", as was formerly done by Hörstadius, it would be quite impossible to state its limits, some of its actions extending—although with diminishing force—all through the vegetal half. Therefore workers on sea urchin development prefer to use the term gradient instead of organizers. As a matter of fact the conception of a double gradient system is adapted to the problems of determination in the early development of the sea urchin. Probably certain corresponding relations govern amphibian development, at the determination along the egg axis.

That which is essential and new in the gradient hypothesis of Runnström (1928, 1929, 1931) is the *antagonism* between *two* principles existing as gradients along the egg axis, their highest intensity being found at the animal and vegetal poles respectively. This hypothesis was originally founded on two facts: (1) the removal or damaging (by lack of potassium or sulfate ions) of the vegetal region leads to supernormal extension of the most animal differentiation, the apical tuft; (2) the enlargement of the vegetal differentiations, mesenchym and entoderm, caused by treatment with lithium ions, which at that time seemed to be based on an inhibition of the animal material. Later, however, it turned out that this mode of action of the Li^+-action could not yet be considered as proved. Nevertheless this hypothesis has been confirmed in the most impressive way by the transplantation experiments carried out by Hörstadius (Abstract, 1939).

The action of the vegetal principle finds its expression in two different ways: (1) by an induction of entodermal differentiations; (2) by restraining the tendencies of extension of the most animal differentiation, the ciliated tuft. Thus the vegetal material differs from an organizer in the amphibian development, which only induces a certain differentiation. Without paying attention for the moment to the inductive action of the vegetal materials, we will now turn to the capacity of vegetal parts transplanted into isolated animal halves of restraining the tendency of extension of the animal differentiations. Experiments of Hörstadius show micromere material to be twice as active as macro-

mere material. The same faculty is also present in the vegetative parts of the presumptive ectoderm, though to a much lower degree. Thus the decrease of the vegetal principle is clearly demonstrated. The decrease of the animal principle along the egg axis can in the same manner be demonstrated by the number of micromeres necessary to cause the two most animal discs of cells of the 32-cell stage to differentiate into a normal pluteus. This number is four for the more animal disc and two for the less animal disc.

The tendency of extension of the animal differentiations is the expression of the mentioned antagonism. The enlargement of the entoderm in isolated vegetal halves (Hörstadius, 1939) demonstrates a corresponding, though less striking, tendency of the vegetal principle. The demonstrated earlier fixation of the determination (Runnström, 1928: Hörstadius, 1939) in the vegetal than in the animal egg-half suggests an explanation of the fact that the tendency of extension of the vegetal principle asserts itself to a smaller degree than the animal one. Apart from the inhibiting effect of the animal principle on the tendency of extension of the vegetal one, its organizing capability also shows itself in transplantation experiments. An animal half fused together with an inverted vegetal one forces its polarity to a large extent upon the latter (Hörstadius, 1928).

Besides the antagonism between the animal and vegetal principle which by extreme excess of the one can lead to complete extinction of the other, there is one more phenomenon appearing in isolation and transplantation experiments, obviously of great importance to the spatial realization of the two principles. Removal of the most animal material, which normally differentiates into the apical tuft, enables the less animal material to perform this differentiation. Removal of the skeleton forming material, the most vegetal one, causes the less vegetal material to form the skeleton. The same phenomenon occurs in isolated equatorial fragments, in which the animal part differentiates into more animal structures and the vegetal part into more vegetal ones than either one does in its normal position (Hörstadius, 1935). Obviously the *parts of the embryo containing the two principles in highest intensity exert inhibiting effects, restraining the realization of the same principle in regions of lower intensity* (Lindahl, 1936). This phenomenon is most striking in the development of the isolated presumptive entomesoblast, where even ectoderm is formed (Hörstadius, 1935). This regularity, which I would like to call "polar dominance" (not to be confused with the "physiological dominance" of Child, which has a much wider meaning) was already recognized in the vegetal region of the embryo by Boveri in 1901. The same phenomenon was later named *Neukonzentration der Gefälle* by Hörstadius (1935), and *Entmischung* by von Ubisch (1936), terms which can only be considered as formal descriptions.

The animal and vegetal principles, the antagonism between the two and the "polar dominance" existing within them are the bases of all regulation along the egg axis. They are also the condition of the so-called *Ganzfaktor* and the harmonious development in the developmental mechanics of the sea urchin egg. Besides these factors the instant of the definite fixation of determination in the different embryonic parts determines the shaping of isolated fragments, as well as their various combinations.

It must be emphasized that the animal and vegetal graded principles have been demonstrated up to the present only in morphological experiments. Consequently they ought to be called "morphogenetic gradients."

The differentiation of an embryo or a fragment depends—as often pointed out by Hörstadius—on the quantitative relation between the two principles. But also their spatial arrangement and the possibilities of influencing each other seem to be of great importance. Thus a stretching of the egg along the egg axis (Lindahl, 1932) or an equatorial constriction (Hörstadius, 1939) causes an enlargement of the apical tuft. The readiest explanation of this phenomenon, as well as of other similar ones, is given by the assumption that the vegetal principle influences the animal by means of a diffusing compound, and the diffusion path being made less favorable by the treatments mentioned (Lindahl, 1936). This does not, however, imply an indentification of this hypothetical compound with the vegetal principle itself (Child, 1940).

ON ALTERATIONS OF THE DETERMINATION BY CHEMICAL TREATMENT

Nowadays nobody will deny that the vegetal and animal principles discussed are to be looked upon as the expression of certain metabolic processes (Child, 1940). The discovery of these processes must be one of the next tasks of developmental physiology.

The relation between the animal and vegetal principles can be changed not only by micrurgical methods, but also by destruction of certain regions of the embryo or interference with the metabolic processes upon which the two principles are based. Such a local destruction, caused by the environmental conditions, will chiefly be localized in the vegetal parts and can, for instance, be caused by lack of K^+-ions (Runnström, 1925), treatment with SCN^- in hypotonic solution (Runnström, 1928) or by a short treatment with weak Hg^+ concentrations (Lindahl, 1936). The changes of the vegetal material caused by lack of SO_4-ions should also be mentioned here. All these cases show an enlarged ciliated tuft in consequence of a partial or complete deficiency of the vegetal principle.

Far more interesting are the results obtained with complete embryos, which, without being locally destroyed, become animalized or vegetalized by treatment with certain chemical agents. That is, they differentiate in a more vegetal or more animal way than normally. The terms "animalized" and "vegetalized" are used to describe briefly displacements of the organ limits (Fig. 1) in vegetal or animal direction. They do not coincide with "endodermization" or "ectodermization", since vegetalization does not necessarily include endodermization or animalization ectodermization. Being treated with a suitable dose the embryos will be able to live and differentiate. (A great difficulty in judging the developmental results in such experiments depends on the fact that the chemical treatment not only causes the intended changes in morphogenetic harmony, but also inhibits more or less the normal differentiation, without causing destruction. The recognition of such a circumstance, although not always possible, is of great importance, since otherwise false conclusions are likely to be drawn.) It may be concluded that the treatment chiefly inhibits or advances some metabolic processes of morphogenetic importance, leaving other vital processes undisturbed. The interference causing vegetalization which has been most investigated is the treatment of the fertilized egg with lithium ions according to Herbst. An animalization without destruction of vegetal embryo parts can be obtained by treating the unfertilized egg with sulfocyanide or iodide in the absence of calcium as first performed by the author (1933).

The similarity between the morphological forms which were obtained on the one hand by Li^+ treatment and animalizing treatment and on the other by micrurgical methods (Figs. 2–3) is of great importance in the analysis of the changes in the metabolism caused by the treatments in question. This concordance justifies the conclusion that the Li^+ treatment changes the relation between the two principles in such a way that the animal principle becomes weaker or the vegetal stronger. A combination of these two possibilities might also be considered. In the animalized embryos the treatment correspondingly either weakens the vegetal or strengthens the animal principle.

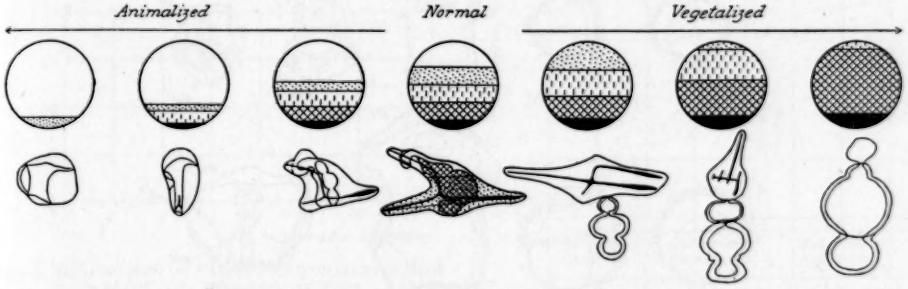

FIG. 1. DIAGRAM OF THE DISPLACEMENT OF ORGAN LIMITS IN EMBRYOS ANIMALIZED BY TREATMENT BEFORE FERTILIZATION AND VEGETALIZED BY Li^+ TREATMENT

In the middle the presumptive meaning of the material in the normal development according to Hörstadius 1935. By aid of this scheme the distribution of the presumptive organs in the different cases of animalization and vegetalization has been drawn. Note the rotation of the plane of the oral field accompanying vegetalization.

Metabolism and determination

Since the sea urchin embryo is a pronounced aerobic organism, it can be expected that a great number of metabolic processes are directly or indirectly coupled with oxygen consumption. Thus a diminution or a reinforcement of certain metabolic processes may be observed in corre-

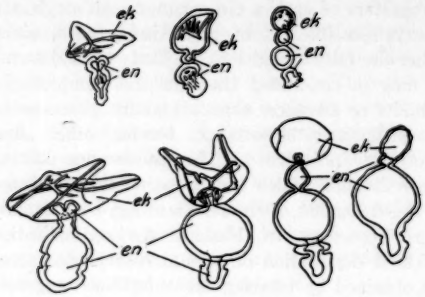

FIG. 2. PARACENTROTUS LIVIDUS, EMBRYOS OF VEGETAL TYPE

Upper row obtained by cutting down the animal material (from Hörstadius, 1935); lower row by lithium ion treatment (from Lindahl and Öhman, 1938). *ek* ektoderm; *en* entoderm.

consumption after the sudden rise at fertilization continuously increases during the first 24 hours of development. "There is no maximum, no S-shaped curve and no 'rhythmic' respiration." Later, more detailed researches have revealed somewhat different facts. Thus the respiration during the first 6 cleavages increases according to an exponential function of time (Gray, 1927; Lindahl and Öhman, 1938). This increase gradually ceases and the oxygen consumption remains constant from two to two and a half hours (22.0°C). During this first period of development, lasting till shortly before the migration of the primary mesenchyme, the curve of respiration is S-shaped (Fig. 4). A further increase of respiration which begins suddenly, constitutes the limit between

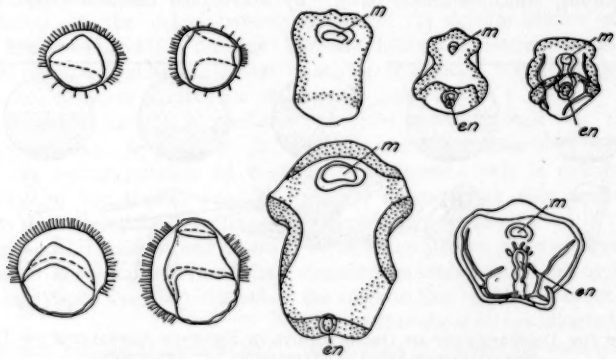

FIG. 3. PARACENTROTUS LIVIDUS, EMBRYOS OF ANIMAL TYPE

Upper row obtained by cutting down the vegetal material (from Hörstadius, 1935 and 1936); lower row by animalizing treatment before fertilization (from Lindahl, 1936), *en* entoderm; *m* stomodaeum.

sponding changes in oxygen consumption, and measurements of the respiration might give some orientation about the changes caused in the metabolism.

[*Editorial note:* At this point in Dr. Lindahl's manuscript a page number is missing. Since it is impossible to communicate with the author to ascertain whether there has been a misnumbering of the pages or whether a page has been lost in transit, the paper is being published in the form in which it has reached the Office of the Editor.]

The changes of normal respiration during development

The respiration of the developing normal sea urchin egg was first investigated by Warburg (1915). He showed that the rate of oxygen

this and the following period of development, which lasts till the end of gastrulation (Lindahl, 1940). Characteristic for this second period is a constant increase in respiration, the migration of mesenchyme and gastrulation. During the third period of development the oxygen consumption still rises but much more slowly than earlier. At this time the differentiation of tissues and the formation of body shape is taking place. This period is arbitrarily considered to end with the breaking through of the mouth. The tissue differentiation and the formation of the body shape are far from being finished at this moment, but as the metabolism later on does not depend merely on materials stored in the egg, investigations of the metabolism in later stages are of less interest (Lindahl, 1940). A survey of the behavior of

normal respiration during these three periods of development is given in Fig. 5.

On the action of sulfate ion deficiency

At the end of the last century Herbst found that sulfate ions are necessary for the normal development of the sea urchin egg and that they are of importance only in the late blastula and later stages. Lack of $SO_4^{=}$ leads especially to inhibition of the vegetal parts of the embryo. The entodermal cells are opaque and yellowish and do not stretch themselves normally; thus the entodermal wall remains too thick and often not subdivided. The primary mesenchyme does not, as normally, arrange itself into the well-known skeleton-forming ring, but remains stored in the neighborhood of the intestine. This may be accounted for by the inhibition of factors in the mesenchyme cells or in

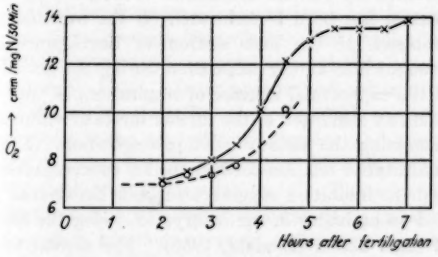

FIG. 4. RESPIRATION OF PARACENTROTUS LIVIDUS EGGS AT 26.0°C AS A FUNCTION OF TIME

Solid line = normal respiration; broken line = respiration in 0.081 mol LiCl (from Lindahl, 1939).

the ectoderm, which direct their movements. The region covered by the apical tuft extends itself and the limit between entoderm and ectoderm is shifted toward the vegetal pole. The bilateral organization is more or less suppressed. In extreme cases the embryos may become radially symmetrical.

Though these experiments belong to those which have led to the conception of the antagonistic principles, later research in this field has not brought the solution of the physiological problems of determination nearer, the lack of $SO_4^{=}$ not exerting an action until the determining processes are to a great extent already passed. Nevertheless the localization of certain metabolic processes has been demonstrated in this way.

The animalization which takes place here differs in many essential respects from that caused by treatment of the unfertilized egg. The inhibitions and structural disturbances go hand-in-hand with a slight reduction of oxygen consumption (Lindahl, 1935), which appears simultaneously with the need of $SO_4^{=}$ and thus earlier than the visible inhibitory alterations.

The rôle of the $SO_4^{=}$ in the metabolism of the developing sea urchin egg is still unknown. It has, however, been shown that a culture in $SO_4^{=}$-free sea water gives off more differentiation-inhibiting matter to the medium than does a culture in normal sea water (Lindahl and Stordal, 1937). To test this, the larvae were filtered away, the sea water completed and used as medium for freshly fertilized eggs. The formation of the inhibiting substance in the absence of $SO_4^{=}$ could be demonstrated still better after extraction of the whole cultures with ethyl ether (unpublished experi-

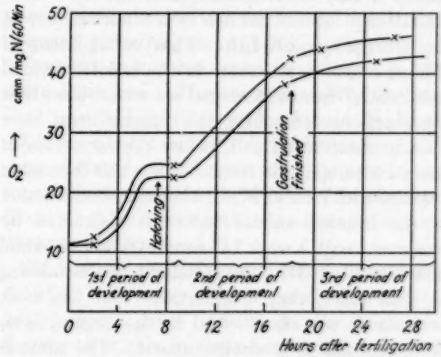

FIG. 5. CHANGE IN RESPIRATION DURING DEVELOPMENT OF THE EGGS OF TWO DIFFERENT FEMALES. PARACENTROTUS LIVIDUS
T = 22.0° (from Lindahl, 1939)

ments of the author). As in many other tissues and organisms, a phenosulfatase has also been demonstrated in the sea urchin egg (Lindahl, 1936). Thus there is reason to assume, that $SO_4^{=}$ is needed for the detoxication of intermediary compounds containing cyclical hydroxyl groups. Whether these poisonous compounds are formed in connection with protein metabolism, as assumed for mammals, or with other processes, still remains a problem. Intermediary products in the formation of the pigment echinochrome, which, according to recent research (Kuhn and Wallonfels, 1939), is a naphthoquinone derivative, may also be thought of. Remarkable is the simultaneous commencement of the need of $SO_4^{=}$ and of the increase in respiration just before the migration of the skele-

ton-forming cells. The fact that the vegetal region of the embryo—the chief seat of the formation of toxic compounds in absence of $SO_4^{=}$—acquires a much stronger power of reducing redox indicators just at this moment, suggests that new metabolic processes are beginning here.

The general features of the disturbances caused by lack of $SO_4^{=}$ demonstrates a localization of the metabolic processes giving rise to the need for $SO_4^{=}$ in the vegetal regions of the embryo. Further information has been obtained by keeping isolated animal and vegetal halves in an $SO_4^{=}$-free medium (Lindahl and Stordal, 1937). The animal halves behave just as they would in normal sea water and are thus not able to form the toxic products. This statement can, however, not be extended to the animal half in its normal connection. Nevertheless it may be concluded, that the toxic compounds are formed neither in the normal nor in the enlarged apical tuft. That enlargement of this structure is the same in the isolated animal half in $SO_4^{=}$-free as in normal sea water shows that the reactions controlling this process must have already come to an end, before the formation of the toxic compounds starts. Thus this formation appears with lack of $SO_4^{=}$, when the animalization in the isolated animal halves is restrained by treatment with a weak Li^+-concentration (Lindahl and Stordal, 1937). As entoderm still is missing in such cases, they demonstrate that the toxic compounds are also formed in the vegetal ectoderm, though to a smaller extent. The same is suggested by results on entoderm-free embryos, obtained by treatment prior to fertilization. The stretching of the cells in the oral field appears to be especially influenced here, thus suggesting a difference between the dorsal and ventral sides with respect to these metabolic processes.

Isolated vegetal halves in $SO^{=}_4$-free sea water are still more affected than the corresponding material in normal connection with the animal half (Lindahl and Stordal, 1937). The best reason for this is, that the vegetal half, according to experiments of Hörstadius (1936), has more vegetal character when isolated than under normal conditions. Other explanations, taking into account diffusion of the toxic compounds into the animal half, are also possible. By appropriate treatment with Li^+, isolated animal halves may be brought to form entoderm (v. Ubisch, 1925). This entoderm in lack of $SO_4^{=}$ behaves just as the normal entoderm of an entire embryo (Lindahl and Stordal, 1937). From this we may conclude, that the metabolic processes leading to these toxic intermediary products are not confined to a certain material but to a certain determination and differentiation. Consequently these reactions are of no importance in the origination of the vegetal principle but are dependent on the latter and coincide largely with its extension. This is supported by the fact that the production of toxic compounds in lack of $SO_4^{=}$-ions is initiated at a much later stage than that at which the morphogenetic actions of the vegetal principle may be detected in transplantation experiments.

The action of lithium ions on metabolism, protoplasmic structure, and morphology

Since determination is fixed progressively during the twelfth to sixteenth hour of development (Hörstadius, 1936) and a vegetalization is only obtained by lithium treatment in earlier stages, interest has been concentrated on the metabolic processes of the first section of development. Brought into an egg suspension during the period of the exponential increase of respiration, Li^+ produces an inhibition of the further increase without decreasing the already existing respiration. The quantitative relation between the Li^+ concentration and the inhibition suggests a reaction between Li^+ and an activator in the embryo following the law of mass action (Lindahl, 1936). The similar inhibition of fermentation and respiration in yeast cells by Li^+ as well as the inhibition of the dehydrogenation of hexosemono- and hexosediphosphoric acids with broken eggs as enzyme material and methylene blue as acceptor (Lindahl, 1936), or in the presence of pyocyanine and oxygen as acceptor (Lindahl and Öhman, 1938), made it tempting to think that even in the living sea urchin embryo we are dealing with an inhibition of a carbohydrate oxidation.

To demonstrate the exponential increase of the respiration, Gray (1927) has already made the assumption that the respiration during cleavage consists of two parts, one constant and one increasing. The earlier measurements of respiration in Li^+-cultures apparently confirming this, it was attempted to support this idea by other facts. It was shown (Lindahl and Öhman, 1938) that the absolute activation of respiration by pyocyanine is the same shortly after fertilization and 9 hours later, though respiration has been doubled in the meantime. Thus the action of the pyocyanine seems not to affect that part of the respiration which has arisen between the two stages, but only

that existing shortly after fertilization. This will remain constant until the 9-hour stage and it later also begins to rise. The recent determinations of the respiratory quotient referred to below are in harmony with these results.

The specific inhibitors of carbohydrate breakdown offer a further possibility of penetrating into these problems, their action possibly being limited to the increasing part of the respiration, since carbohydrates would presumably be the substrates of this part. Monoiodoacetic acid amide does, however, not only suppress the building up of the increasing part of respiration, but inhibits also the respiration already present shortly after fertilization. (Lindahl and Öhman, 1937). Glyceric aldehyde, the action of which on the glycolysis of the chick embryo has been intensively studied by Needham and his coworkers, inhibits principally the further increase of respiration when brought into the suspension immediately after fertilization, leaving unchanged the respiration already present (Lindahl, 1939). Later unpublished experiments of the author show, however, that higher concentrations in the eggs of some females inhibit even the constant part of respiration, not only depressing the further increase as does Li^+. Characteristic for this action is, however, a certain lag, suggesting secondary reactions at work. This lack of specificity of the action of the glyceric aldehyde together with the heavy destruction of the embryos already brought about by weak concentrations, which inhibit the respiration only to a very small extent, may perhaps be accounted for by a reaction with amino groups. According to Lehmann and Needham (1938) a nonphosphorylating mechanism of glycolysis may be distinguished from a phosphorylating one by means of the monomeric and dimeric forms of glyceric aldehyde. The respiration of the sea urchin embryo is equally affected by the two forms (Lindahl, 1940).

The experiments with "specific" inhibitors of carbohydrate breakdown have so far not contributed to the elucidation of the rôle played by carbohydrates in sea urchin development. It seemed difficult, besides, to combine the idea of an increasing carbohydrate oxidation existing in addition to a constant one of another kind with an RQ of 0.90 in fertilized eggs. This value was first determined by Warburg (1915) and has later been confirmed by several authors (Lindahl, 1936). All these determinations are performed with the three-manometer method of Warburg. In unpublished experiments of the author on the RQ during development of the sea urchin egg the same method was used and the fact established, that the pH of the cell suspension is lowered in the vessel, where the carbon dioxide formed is not absorbed. An equal respiration in the two vessels provided with KOH and H_2SO_4 respectively being the basis of the determination of RQ, this condition can hardly be recognized as fulfilled, when the pH in one vessel is lowered. So a modification of the method of Meyerhof and Schmit was planned and preliminary experiments carried out by my coworker Öhman (1940). In the 1–2 hour stage, the RQ was found to be 0.73 ± 0.01, in the 7–8 hour stage 0.85 ± 0.01. Accordingly fat seems to be the chief substrate burned shortly after fertilization. A calculation of RQ of the part of respiration, arising between these two stages, assuming that the fat oxidation remains unchanged, reveals a value of 1.00. In fact this part of respiration appears to be an *oxidative carbohydrate breakdown*. The analysis of total carbohydrate and fat (Ephrussi and Rapkine, 1928; Hayes, 1938) do not contradict this interpretation. The data of Hayes present a constant decrease in total fat during the second to ninth hour of development. However these determinations seem to be impaired by great errors.

As long as the respiration increases exponentially, Li^+ obviously acts on the metabolism in *a fairly specific way*. Added to the suspension shortly after this increase has ceased, it *inhibits the respiration in another way* (Lindahl, 1939). In this stage Li^+ inhibits not only the further increase of respiration but also the existing respiration. This inhibition does not reach its maximal value shortly after the addition of Li^+ as in earlier stages, but continues to increase. Furthermore, the inhibition of a certain Li^+ concentration is independent of the temperature during the exponential increase of respiration (Lindahl and Öhman, 1937), while the late inhibition is greater at higher than at lower temperatures (Lindahl, 1939). The embryos show a much more pronounced general sensitivity to Li^+ in these later stages than in earlier ones, culminating in destruction and death. It is, however, easy to suggest a causal connection between the changes in the colloidal structure of the protoplasm, caused by Li^+ (Runnström, 1928, 1935) and more marked in the later stages, on the one hand, and the late inhibition of respiration and the general sensitivity of these stages on the other. Certainly a coarsening of the protoplasmic structure by the action of Li^+ could be demon-

strated in earlier stages (Runnström, 1928; Lindahl, 1936). That this coarsening does not appear to determine the inhibition of respiration in earlier stages may be explained by the protoplasmic colloids being considerably less sensitive in these stages. Further the protoplasmic structure does not play the rôle of a limiting factor, the respiration already being depressed by the specific action.

Now we must turn to the question whether there is any causal dependence between the inhibition of metabolism and the vegetalization caused by Li^+ or whether these two actions are to be looked upon as parallel phenomena. The first mentioned possibility would mean that the animal principle is connected directly or indirectly with the metabolic processes which are inhibited by Li^+. In favor of this may be cited the observation that eggs, the respiration of which is less inhibited by Li^+, will also be less vegetalized than those in which respiration is more inhibited. However, a much better argument may be based on the following facts: Li^+ inhibits reversibly the exponential increase of respiration. A short treatment thus causes a deficiency in metabolism, the amount of which depends on the duration of the treatment, the steepness of the respiration curve during the period of treatment, and the Li^+ concentration. Treatment during short equal periods of time with the same concentration of Li^+ would thus cause deficiencies about proportional to the increase of respiration during the different periods. Were the vegetalization possibly caused by the deficiency in question, it too should vary in the same way. This is in fact the case (Lindahl, 1940). If embryos are treated in 3-hour periods (developmental temperature 22°C) from fertilization, then those treated during the first period show a weak, those during the second period a strong, and those in the third period again a weak vegetalization. Compare with this the S-shaped form of the respiration curve in Figs. 4–5. Up to 9 hours after fertilization a short treatment thus causes a vegetalization which is weak or strong according to whether the curve of normal respiration is more or less steep during the treatment. This result strengthens the hypothesis, that *a causal relation exists between the part of respiration inhibited by Li^+ and the animal principle.* It does not, however, exclude the possibility that the increasing respiration and the metabolic processes conditioning the animal principle run parallel. The latter would mean that the processes which constitute the basis of the increase of respiration and the animal principle, are enacted simultaneously and behave similarly towards Li^+.

After 9 hours from the time of fertilization Li^+ treatment of short duration causes a very weak vegetalization or none at all. (Lindahl, 1940). Thus the inhibition of respiration induced by Li^+ in later stages has no direct relation to vegetalization (Lindahl, 1940). If, however, the treatment is started in earlier stages and extended over the 12-hour stage, then it will exercise a stronger vegetalization the longer it is continued (Hörstadius, 1936; Lindahl, 1940). The treatment in earlier stages thus enables Li^+ to exercise a vegetalizing action in the later ones. This must signify that the fixation of the determination is delayed by the earlier Li^+ treatment. Under these conditions either the same action of Li^+ may be realized in the later stages as in the earlier ones, or Li^+ exerts here another influence, which directly or indirectly leads to a stronger effect of the earlier intervention in the metabolism.

It has often been attempted to gain insight into the mechanism of the morphological action of Li^+ by combining the Li^+ treatment with other agents. Thus elevation of the K^+-concentration of the sea water weakens the vegetalizing action of Li^+ (Runnström, 1928; Lindahl, 1936). This fact is, however, difficult to interpret, because an elevation of the K^+-concentration by itself may lead to an enlargement of the apical tuft and consequently to an animalization, which apparently is realized by means of a weak injury of the vegetal material. Nevertheless, measurements show the respiration to be increased by the elevated K^+-concentration (Lindahl, 1936). In combination with Li^+ the depression caused by this ion is thus levelled by action of the higher K^+-concentration. A close study of the behavior of the two parts of respiration would in this case be rather difficult to carry out.

The combination of Li^+-treatment with different agents inhibiting the electron transfer in the respiratory mechanism has been intensively studied. Carbon monoxide (mixed with oxygen) (Runnström, 1933) as well as KCN (Lindahl, 1936) and partial anaerobiosis (Lindahl, 1940) strengthen the vegetalizing action of Li^+. In the absence of Li^+ only CO causes a vegetalization (Runnström, 1928; Hörstadius and Strömberg, 1940), but it is said to produce an animalization in entire eggs as well. The interesting result (Hörstadius and Strömberg) that CO treatment

causes an animalization in animal halves and vegetalization in vegetal ones suggests an unspecific action being in play. The assumption that CO delays the fixation of the determination, thus giving the predominant principle in the two separated halves a chance of carrying itself through, offers a possibility of explanation.

The equal action of the two respiratory poisons and the partial anaerobiosis when combined with Li^+ shows that we are hardly dealing with a specific quality of the two poisons. The oxidation-reduction state of the cellular components is changed in the direction of being more reduced by the depression of electron transfer. It is thus possible that the substances on which Li^+ acts more or less directly are more influenced by Li^+ when in a more reduced state (Runnström and Thörnblom, 1936). Again, the depression of the electron transfer undoubtedly leads to disturbances of the protoplasmic structure caused either by deficient supply of energy or by accumulation of acid intermediary products. Combining Li^+ treatment with the action of weak organic acids strengthens, however, the vegetalization (Lindahl, 1940). Thus the strengthening caused by depression of respiration may as well be referred to an accumulation of acid intermediary products as to changes in the oxidation-reduction state of certain systems in the cells. For the time being we may tentatively make the coarsening of the protoplasmic structure, which is common to the depression of oxygen transfer as well as the action of acids, responsible for the strengthening of the vegetalization by Li^+. This would trace an action of different agents back to one ground-phenomenon and would eventually even apply to the action of Li^+-treatment extended over the 12-hour stage.

There are many descriptions in the literature of exogastrulae obtained by the most different means and classed with embryos modified by Li^+ treatment. Nowadays it must be considered proved, that exogastrulation can appear as a consequence of vegetalization as well as of interventions into the gastrulation mechanism. In the latter case, the embryos are perfectly normally proportioned. The *exogastrula* is by no means identical with the *vegetalized* embryo. Detailed figures and statements prove the existence of vegetalized cases obtained with other agents than Li^+, including such different treatments as carbon monoxide, auxin, janus green and crowding. Thus Li^+ does not act specifically in the sense that it is the only agent causing vegetalization (Child, 1940). The action is, however, so far specific that Li^+ inhibits certain metabolic processes, leaving others relatively unaffected. In this respect an agreement with other vegetalizing agents is to be expected.

If the animal principle is connected with some kind of carbohydrate breakdown, as has been shown to be probable, it would be possible to produce a vegetalization with the aid of compounds which selectively inhibit carbohydrate breakdown. Experiments of this kind, however, turned out negatively (Lindahl, 1940; Needham and Needham, 1940). This may depend on the fact that the inhibitors used—monoiodoacetic acid, glyceric aldehyde, phloridzin—not only inhibit the carbohydrate breakdown, but also other vital reactions, this being obvious from measurements of respiration as well as from destruction of the embryos (Lindahl, 1940). The same point of view may even serve as an explanation for the rather contradictory results obtained by Hörstadius and Strömberg (1940). They found monoiodoacetate to cause an animalization in entire eggs and a vegetalization in animal halves. Treatment with phloridzin led in entire eggs to animalization, in isolated animal halves, on the other hand, to animalization as well as to vegetalization. In entire eggs treated with this compound before fertilization, the author obtained a vegetalization (Lindahl, 1940).

Animalization by treatment before fertilization and its mechanism

Sulfocyanide and, in the second place, iodide ions have shown themselves to be very active in causing animalization after treatment of unfertilized eggs. Also other ions such as SO_4^{--}, Br^+, tartrate, Li^+ are able to bring about animalization in the same way, being, however, less efficient. In this rank belongs probably also an unknown compound, contained as an impurity in a KCl-preparation from Schering-Kahlbaum (pro analysi). It had the same action as the above-mentioned ions and could be removed by recrystallization (Lindahl and Öhman, 1938). As the treatment lasts several hours, it is necessary to eliminate those processes which lead to "overripeness" of the eggs and counteract the animalization. Since these reactions are bound to the presence of Ca-ions (Lindahl, 1936; Schechter, 1937), the treatment is performed in Ca^{++}-free sea water. This is, however, by no means a necessary condition, but makes the method more reliable.

It is obvious that the action in question is not a

specific one since it is brought about by such different ions. Moreover the ions create certain conditions in the cell enabling specific reactions to take place. According to this, the animalization resulting in some cases from a treatment with Ca^{++}-free sea water alone (Lindahl, 1936) is not very surprising. Certainly we are dealing with some kind of impurity in the chemicals used for the artificial Ca^{++}-free sea water or in the vessels employed, which causes the same kind of alteration in the egg as the ions mentioned above.

The oxygen consumption during the treatment has proved to be of decisive importance. If the treatment is carried out under an oxygen pressure of 2 per cent or less, in the dark in an atmosphere of 5 per cent O_2 + 95 per cent CO or in $6 \cdot 10^{-5}$ mol KCN, the animalization fails to appear (Lindahl, 1936). In all these cases the respiration of the unfertilized egg is hardly inhibited at all, whereas an inhibition will appear as soon as the spontaneous rise of respiration, first described by Warburg, takes place. (This phenomenon is considered by Tyler, Ricci and Horowitz (1938) to be the consequence of bacterial activity. However, their experiments show that certain processes in the egg, connected with "ageing", are of importance.) An increased respiration during the treatment thus seems to be the decisive process in animalization. The same is shown by experiments in which the oxygen consumption is accelerated during the treatment, by addition of the reversible redox compound pyocyanine (Runnström and Thörnblom, 1936). The animalizing process is here considerably accelerated. The specific reaction leading to animalization during the treatment thus consists in an oxidation or is coupled with such a reaction. Where these oxidations come in, is still completely unknown. Attempts to measure the respiration during an animalizing treatment have never succeeded, because the animalization of the eggs always fails to appear when simultaneous measurements of the respiration are made. Probably certain very labile structural conditions in the cell, which are disturbed by shaking during measurement of respiration, play an important rôle in the processes leading to animalization.

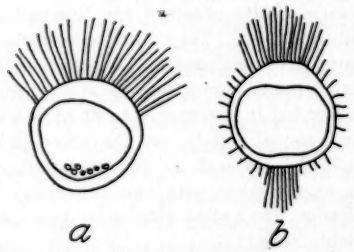

FIG. 6. EMBRYOS OF PARACENTROTUS LIVIDUS ANIMALIZED BY TREATMENT BEFORE FERTILIZATION

(a) with vegetally situated skeleton forming cells *s*, later forming an triradiate spicule. (b) with a secondary ciliary tuft in the same position (from Lindahl, 1936).

Measurements of respiration on animalized embryos during the exponential increase of respiration show striking divergences from the state of the normal embryo (Lindahl, 1936). One of these concerns the susceptibility of the respiration to Li^+, which has much increased. Thus certain metabolic systems are altered by the treatment. An interpretation of these facts is not yet possible, nor is it possible to decide whether the treatment primarily causes a weakening of the vegetal or a strengthening of the animal principle.

When the animalization has proceeded so far that all vegetal organs have disappeared, one would expect further progress of this process to be manifested in a greater and greater increase of the apical tuft and the ciliated band at the expense of the lower epithelium. Instead we find (Fig. 6), that a new tuft takes the place of the skeleton-forming cells at the vegetal pole. That we are here indeed dealing with a new physiologically functioning animal pole, may be concluded from experiments in which eggs animalized by treatment before fertilization are exposed to the action of Li^+. In embryos which have been moderately animalized the vegetal differentiations will now appear and nearly normal or slightly vegetalized embryos develop. This is also the case in embryos which should have differentiated two apical tufts. However, the mesenchyme and the entoderm are not, as in the normal egg, formed from the most vegetal material, which here gives rise to ectoderm, but from the material located just on the vegetal side of the egg equator (Fig. 7). Consequently, without any displacement of material, an inversion of the polarity has taken place in the vegetal third of the embryo. At present this phenomenon is most easily explained by aid of the "polar dominance". At the moment during the animalization, at which the vegetal principle has been totally suppressed, the animal principle, in very low intensity, holds the vegetal region of the egg. Because of the great distance, the most vegetal

part of the egg will, however, be that least exposed to the inhibitory action emanating from the most animal parts and tending to suppress the animal principle in lower intensity. Thus, this is the only position where a secondary animal pole and apical tuft may arise.

On the localization of certain metabolic processes

The spatial arrangement of the animal and vegetal principles can be demonstrated by microrurgical methods, but because of the small size of the sea urchin egg—diameter about 80μ—the demonstration of localization of metabolic processes meets with difficulties. Vital staining with redox indicators and the following of reduction under anaerobic conditions have demonstrated the existence of regions with different powers of

FIG. 7. EMBRYOS OF PARACENTROTUS LIVIDUS IN DIFFERENT STAGES OF DEVELOPMENT, ANIMALIZED BY TREATMENT BEFORE FERTILIZATION AND TREATED WITH LITHIUM IONS AFTER FERTILIZATION

The dotting shows the pigment ring of this species lying below the equator in the uncleaved egg (from Lindahl, 1936).

reduction. In otocytes and in various developmental stages up to the late blastula, a reduction gradient exists with the most rapidly reducing region at the animal pole (Child, 1936). Shortly before the migration of skeletal-forming cells a second reduction gradient appears, the primary mesenchyme cells becoming the most rapidly reducing cells of the organism. These two reduction gradients remain until the prism stage, when the gradient pattern becomes more complicated in connection with the formation of stomodeum and arms. Striking is the simultaneous appearance of the vegetal reduction gradient, the sudden commencement of the further increase of respiration and the appearance of toxic intermediary products, normally depoisoned by $SO^{=}_{4}$. Under the action of Li^{+} these two reduction gradients are, it is proposed, totally or partly obliterated or even reversed.

The extent of the animal reduction gradient in the blastula stage is said to be closely related to the size of the future ectoderm and to vary, parallel with this, under experimental conditions (Ranzi and Falkenheim, 1937). A limiting value, separating future entoderm and ectoderm, is claimed to have been demonstrated by aid of different rH indicators.

Only the well-known micro methods of Linderström-Lang and Holter have made quantitative measurements in different parts of sea urchin embryos possible. Measurements with aid of the diver method of Linderström-Lang on isolated animal and vegetal halves have shown the respiration to be equal in the two fragments in the 7–9 hour period as well as 12 and 28 hours after fertilization (Lindahl and Holter, 1940). This means that Child's conception of a respiration gradient, with its highest intensity at the animal pole as the basis of polarity, cannot be valid. Because of technical difficulties measurements of respiration on animal and vegetal halves are not possible shortly after fertilization. Though equal in the 7–9 hours stage, the respiration of the two fragments might be different shortly after fertilization, the increasing part of respiration being chiefly limited to the animal half. Against such a localization may be put the equal inhibition or activation of respiration caused by Li^{+}, glyceric aldehyde, or pyocyanine in the two halves. (The experiments with Li^{+} are here less conclusive, the measurements being performed after the end of the exponential increase of respiration. In this stage the late unspecific kind of inhibition enters.) Although the vegetal reduction gradient appears simultaneously with the sudden commencement of the further increase in respiration shortly before the migration of the primary mesenchyme, this increase seems not to be limited to the vegetal half, the two halves showing the same O_2-consumption 12 as well as 14 hours after fertilization (Lindahl and Holter, 1940). Thus several facts suggest that the reducing, substrate activating systems of the embryo are not the limiting factors in oxygen consumption, which is more likely to be located in the electron transporting chain of respiration. Similar conditions also seem to be found in the amphibian embryo, where the stated differences in oxygen consumption between different regions of the embryo do not nearly attain the magnitude of those found in anaerobic glycolysis.

Animal and vegetal materials have furthermore been shown to contain equal amounts of dipepti-

dase in early cleavage stages as well as in blastulae and plutei (Holter and Lindahl, 1940) and no changes could be demonstrated during development.

It is thus obvious that a localization of metabolic processes as the basis of the animal and the vegetal principles has not yet been demonstrated.

ON THE DETERMINATION OF THE DORSO-VENTRAL AXIS

If a segmenting sea urchin egg is dissected by meridional cuts, then the fragments obtained, even if they are eighths of the entire egg, acquire dorso-ventral organization. This shows that the determination of the dorso-ventral axis is very labile in this stage and that each part of the circumference may develop into the ventral or dorsal side. What is the mechanism guaranteeing the occurrence of only one ventral side in the normal embryo? Concerning this problem the results of some experiments give information. If unfertilized sea urchin eggs are forced through a narrow pipette and immediately fertilized they maintain elongated form. If this form remains sufficiently during development, two ventral sides (oral fields) appear, one at each of the two ends (Lindahl, 1932). From this result it appears, that a ventral side suppresses the genesis of other ventral sides in the embryo. This conclusion is also supported by constriction experiments (Hörstadius, 1938). If the distance between two parts of the circuit of the egg equator exceeds a certain value, or if the contact between such parts is greatly diminished by a constriction, the suppressive action of the ventral side does not assert itself through the entire egg.

Certain facts indicate that the ventral side arises independently of the point of entrance of the sperm (Hörstadius, 1928) but is conditioned by certain local colloidal structures of the cortex (Förster and Örström, 1933). It seems further to be favored in some respects in reference to other parts of the egg and is thus superior to them, as may be concluded from experiments with stretched eggs (Lindahl, 1932). Here the end of the egg, which passes first through the narrow pipette and which is subjected to a stretching, develops into the ventral side. If, however, this end is poisoned by very strong vital staining with Nile Blue Sulfate, then the other end, which is now relatively favored, becomes the ventral side. This view is further supported by recent experiments by Pease (1940), in which the eggs are brought during cleavage into a diffusion gradient of various poisons, the part of the egg treated with the lowest concentration developing into the ventral side. Moreover, we know that stretching of eggs by means of centrifuging increases the activity of the indophenol blue oxidase (Navez and Harvey, 1935) as well as of the normal dehydrogenase system (Ballentine, 1940). Unpublished experiments of H. Holter and the author have, however, shown the respiration to be equal after fertilization in normal eggs and in those stretched by means of a narrow pipette.

It is possible to influence the position of the ventral side and consequently also the dorso-ventral axis by centrifuging (Runnström, 1925; Lindahl, 1932; Pease, 1939). The protoplasmic inclusions accumulated in one part of the egg and remaining there during development, seem to be the important factor, the ventral side arising in that part or its neighborhood. One cannot escape from the impression, that the presumptive "pre-existing" dorso-ventral polarity, in many cases of centrifuged eggs, co-operates with the stratified inclusions in localizing the ventral side, since it often appears at some distance from the former (Lindahl, 1932). This fact led Pease (1939) to the hypothesis, that the ventral side in the normal egg is determined by at least two factors, one of which is a cortical gradient and the other a diffusely distributed substance in the interior. In the centrifuged egg the ventral side is thought to be determined in the region of the greatest interactivity between these two systems.

Measurements on eggs fragmented by centrifugation show a higher dehydrogenase activity of centrifugal fragments than of centripetal ones, which suggests that part of the dehydrogenase system is associated with the granular material (Ballentine, 1940). Centrifugal fragments show a higher respiration than centripetal ones (Shapiro, 1935). At fertilization the oxygen consumption of the latter rises, and becomes about the same in the two types of fragments.

There thus appear certain possibilities of associating the experimentally induced local "favoring," which leads to the development of the ventral side at a certain place, with local changes in metabolism. Especially interesting are the experiments of Pease already mentioned. Here the eggs are brought into a concentration of various substances, of which cyanide, picric acid, 2,4 dinitrophenol, urethane, iodoacetic acid, iodine

and ferricyanide were effective in orienting the dorso-ventral axis, the most inhibited region becoming dorsal, the least inhibited ventral. Experiments performed with malonic acid, arsenate, heavy metal salts, and various alkaloids gave negative results. The fact that local inhibition of cleavage does not necessarily modify the bilateral determination leads to the conclusion that this is not dependent upon a vague "metabolic gradient," but upon a specific enzyme (Pease, 1940). As the whole respiration of the sea urchin egg according to recent results (Lindahl, 1939) must be considered to be cyanide sensitive, the experiments with KCN show that oxidation-reductions are involved under these conditions.

A further very much discussed result may be explained by the fact that the ventral side suppresses the genesis of other ventral sides. When 2—32 cell stages are cut frontally the dorso-ventral axis of the dorsal fragment is inverted. The ventral side thus takes the place of the original dorsal side. It further differentiates much more slowly than the ventral side of the ventral fragment. In the entire embryo, the original dorsal side is the region that has been the least exposed to the suppressive action of the ventral side and is thus the favored region in the dorsal fragment.

Many facts show a close relation to exist between the origination of the dorso-ventral axis and the animal and vegetal principles. Thus the size of the ventral differentiations of the ectoderm, the ciliated band and the oral field are conditioned by the animal-vegetal relation. In animalized embryos they increase at the cost of the low dorsal epithelium, in vegetalized embryos they decrease. From certain stretching experiments the author (Lindahl, 1932, 1936) concluded, that a co-operation of animal and vegetal qualities is necessary for the origination of the organizing presumptive ventral side. The isolation experiments of Hörstadius supplement this view very well. The most extreme animal and vegetal fragments develop into radially symmetrical structures. If, however, they are united in one embryo, bilateral organization appears.

Several attempts have been made to relate hypothetically the origination of the dorso-ventral organization with the animal and vegetal principles. On the one side an oblique course of the vegetal gradient has been purposed (Runnström, 1928; Schleip, 1929), the ventral side being more vegetal than the dorsal one. On the other hand the possibility is discussed that *both* the principles are realized to a higher degree on the ventral than on the dorsal side (Lindahl, 1932, 1936). The latter state could possibly be attained by more favorable diffusion conditions for specifically acting substances provided by special colloid structures on the ventral side. As a matter of fact the protoplasmic colloids of the ventral side behave differently from those of the dorsal side. In favor of these two hypotheses observations on vegetalized, constricted and stretched embryos are quoted. A decision by means of microrurgical experiments seems possible only for the first hypothesis. The experiments performed hitherto do not show any greater extension of the vegetal qualities on the ventral than on the dorsal side (Hörstadius and Wolsky, 1936).

The indispensability of co-operation between the two principles for the origination of the dorso-ventral organization has been established. On the other hand it is debatable whether the existence of vegetal and animal qualities in higher intensity on the ventral than on the dorsal side is to be looked at rather as a consequence than as a condition. Certain cases in which great local discontinuities in the "morphogenetic gradients" are experimentally applied, without determining the ventral side (Hörstadius, 1939), suggest that such conditions cannot in themselves be deciding. At present the assumption of a "favored" region, in elongated eggs the stretched end, in fragments and fused embryo parts the presumptive ventral side, seems to offer sufficient explanation.

The determination of the asymmetry axis is governed by conditions similar to that of the dorso-ventral one. Here also we are dealing with a heteropolar axis, the left-right one which becomes the apico-basal axis of the adult sea urchin. At both ends of this axis hydrocoeles may be formed. The obvious favoring of the one side, in normal development the left one, suppresses the formation of a hydrocoel on the other side (Hörstadius, 1933), thus determining the polarity of the axis. However, there is a great difference. The dorso-ventral axis may fall in each meridional plane, whereas the *direction* of the asymmetry axis is already determined by the fixation of the dorso-ventral axis.

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RUDIMENTARY DIGITS IN PRIMATES

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THE Primates are among the most generalized of mammals in that they possess five well-developed digits on both manus and pes. While this is true of most members of the order, a few forms nevertheless depart from the ordinal rule. In these species, one or more digits normally are so under-developed that they must be regarded as stunted or even rudimentary. This condition usually is more than merely dimensional in nature, for, as will be shown, it commonly involves external characters, skeleton, and musculature. Such type of stunted digit, normal for a given species, falls into a different category from those anomalous rudiments that occasionally occur in man and other primates as well (see Schultz, 1942). The latter do not lie within the scope of this paper.

FOOT

Fifth toe

Man. As is well known, the fifth toe of man decidedly is disposed toward a stunted condition. Wood Jones (1918, p. 79) has succinctly described its dwarfed nature:

> Usually it is but a poor thing; its nail is ill developed, and at times no nail is present. It is peculiarly liable to that circulatory disturbance which manifests itself in chilblains, and not uncommonly it seems in a poor state of nutrition. Most people possess but little power of movement in it, and its skeleton shows that its atrophic condition has affected the bones and joints, for the last two phalanges are very commonly fused together, making it short of a joint as compared with the rest of the toes. Very commonly its axis is not straight, and the toe is humped up and also somewhat bent laterally.

He also pointed out that this cannot be attributed to the wearing of shoes, as often believed, since the little toe exhibits similar characteristics in barefooted groups of man.

Fusion of the last two phalanges of the fifth toe, or lack of the middle phalanx—sometimes called "brachyphalangy"—is not uncommon in both whites and Negroes (cf. Pfitzner, 1896; Schultz, 1926a; Straus, 1927) and is normal in Japanese (Adachi, 1905; Hasebe, 1912). Its occurrence in fetuses proves its congenital nature (Schultz, 1926a; Straus, 1927).

The muscles of the fifth toe, however, are not uniquely atrophic in man. On the plantar surface, as normally in other primates, there is a long flexor tendon, a tendon from the flexor digitorum brevis, an abductor digiti quinti, a lumbrical, a flexor-opponens digiti quinti brevis, and a plantar interosseous. The tendon of the flexor digitorum brevis, however, is absent in some 20 per cent or more of individuals; yet the anthropoid apes also are in default of this tendon at least as frequently (Straus, 1930a). The lumbrical muscle likewise may be lacking, but possibly no more often than that of other toes. A contrahens digiti quinti, a basic pedal muscle, does not occur in man; but its normal suppression again is shared with the three great anthropoid apes.

Dorsally, man's fifth toe possesses a digital tendon from the extensor digitorum longus, while a peroneus brevis and a peroneus tertius are inserted upon its metatarsal bone. The latter, as a normal structure, is indeed a human peculiarity, although appearing as a variant in other catarrhine primates, notably the gorilla (cf. Straus, 1930a; Wells, 1935). A second extensor of the minimus, the peroneus digiti quinti, is normal for lemurs, *Tarsius* and monkeys; it is lacking, except as a rudimentary variant, not only in man but in the anthropoid apes as well (Straus, 1930a).

The muscles of the fifth toe, therefore, do show certain atrophic tendencies in both man and the anthropoid apes when comparison is made with other primates. But the skeleton of this digit seems to be affected only in man; for, to my knowledge, brachyphalangy or a similar condition has not been reported for any other primate.

Second toe

Among primates as a whole, the second toe is well-developed. There are three phalanges, of which the terminal bears a nail. On them are inserted eight muscles: 6 plantar—a long flexor tendon (from the flexor digitorum tibialis or the flexor digitorum fibularis, or both), a short flexor tendon (from the flexor digitorum brevis), a lumbrical, a contrahens, and a pair of interossei—and 2 dorsal—a tendon from the extensor digitorum longus and a slip of the extensor digitorum brevis.

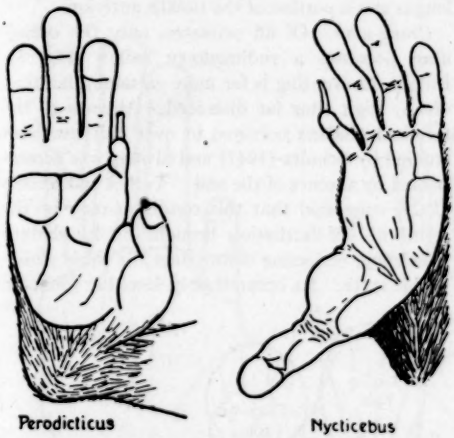

FIG. 1. RIGHT FOOT OF THE POTTO, PERODICTICUS (AFTER MIDLO), AND LEFT FOOT OF THE SLOW LORIS, NYCTICEBUS (FROM MIDLO, AFTER MURIE AND MIVART)

The pincers-like form of the foot in *Nycticebus* clearly is evident; this is concealed in the drawing of *Perodicticus*, for the hallux is shown in a somewhat adducted position.

Lorisidae. The slow lemurs, forming the family Lorisidae, all possess stunted second toes. In the lorises, *Nycticebus* (Fig. 1) and *Loris*—so closely related zoologically that they often are confused with each other—the second pedal digit is relatively quite short. Although there are three phalanges, these are comparatively abbreviated, the middle being especially small. A nail, claw-like as in other lemurs, is present. The foot musculature has been rather thoroughly described by Murie and Mivart (1872), while Ruge (1878, a and b), Glaesmer (1910), Sawalischin (1911) and Forster (1933b) have supplied additional information. The muscular equipment of the second toe appears to be complete save for the frequent absence of a tendon from the flexor digitorum brevis (absent in 4 *Nycticebus:* Murie and Mivart (1), Forster (3); present in 4 *Nycticebus:* Sawalischin; present in 1 *Loris:* Glaesmer) and the lack of the lumbrical (in *Nycticebus:* Murie and Mivart). The former condition is virtually unique among primates, but this particular lumbrical occasionally is missing in catarrhine monkeys (Ribbing, 1909) and man (Le Double, 1897). The tendon of the extensor digitorum longus is weaker than the corresponding slips to the other toes, this in both genera (Murie and Mivart); yet this also can occur in catarrhine primates (Straus, 1930a).

In the other Lorisidae, namely, the potto, *Perodicticus* (Fig. 1), and the closely allied angwán-

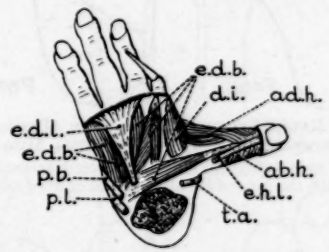

FIG. 2. DORSAL ASPECT OF THE LEFT FOOT OF PERODICTICUS POTTO

The pincers-like arrangement resembles that of *Nycticebus*. Note the absence of a tendon from the extensor digitorum longus (e. d. l.) to the stunted second toe.

tibo, *Arctocebus*, the second toe similarly is stunted (for *Arctocebus*, see Huxley, 1864a). The external and skeletal characters resemble those of the *Nycticebus-Loris* group. The associated musculature, however, differs somewhat, at least in *Perodicticus*. A description of the myology of *Arctocebus* seems not to have been published, and no specimen was available to me for study. The following account of the muscles of *Perodicticus* is derived from my dissection of a specimen of *P. potto* (W. L. S.), supplemented by data given by Van Campen (1859), Glaesmer (1910), Hunter (1925), MacKenzie (1931), and Forster (1933b). For the second toe, there is the normal primate complement except for the regular absence of a tendon from the extensor digitorum longus, which is present but weak in the other lorises (Fig. 2). This tendon was wholly lacking in 4 animals (Hunter, MacKenzie, Van Campen, W. L. S.),

present as a thin filament in one other (Forster). It should be noted, however, that absence of said tendon is not entirely peculiar to the pottos, although a normal character in them alone: for it occasionally is missing in orang-utans and colobine

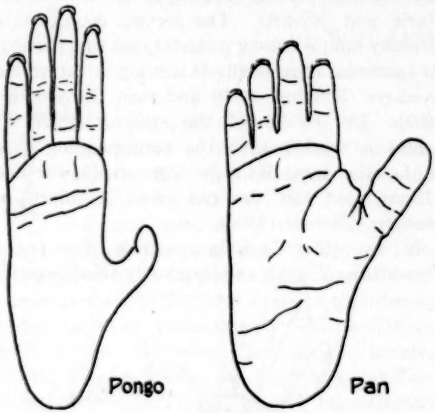

FIG. 3. RIGHT FEET OF ORANG-UTAN (PONGO) AND CHIMPANZEE (PAN). BOTH AFTER MIDLO
The rudimentary hallux of the orang contrasts markedly with the powerful hallux of the chimpanzee.

—long flexor, lumbrical, contrahens, interossei, short extensor—to be well-developed.

Hallux

As a rule, the hallux, or vernacular "big toe", is strongly developed in primates. Upon its two phalanges are inserted six muscles, 4 plantar—a long flexor tendon (derived from one or both of the long crural digital flexors), an abductor hallucis, a flexor hallucis brevis, and an adductor hallucis—and 2 dorsal—an extensor hallucis longus and a slip of the extensor digitorum brevis—while to its metatarsal bone are attached the peroneus longus and a portion of the tibialis anterior.

Orang-utan. Of all primates, only the orang-utan possesses a rudimentary hallux (Fig. 3). Indeed, its stunting is far more extreme than that of any digit thus far discussed. Absence of the terminal phalanx occurred in over half the cases studied by Schultz (1941) and always was accompanied by absence of the nail. Yerkes and Yerkes (1929) suggested that this condition may be the result of self-mutilation brought on by dietary deficiency, endocrine disturbance, or some neuropathic state. Its occurrence in fetal life (Schultz,

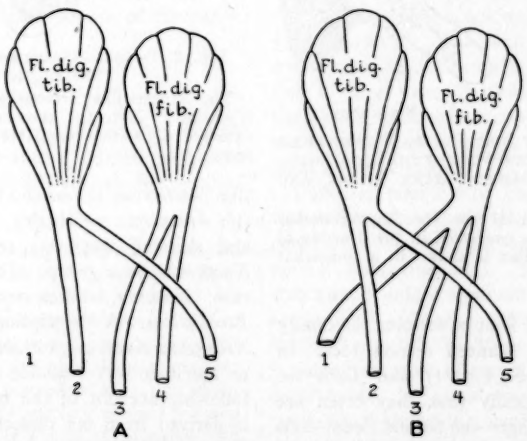

FIG. 4. DIAGRAMS SHOWING THE ARRANGEMENT OF THE LONG FLEXOR MUSCLES OF THE TOES—FLEXOR DIGITORUM TIBIALIS AND FLEXOR DIGITORUM FIBULARIS—IN ORANG-UTAN (A) AND CHIMPANZEE AND GORILLA (B)
The orang normally has no trace of a tendon to the hallux.

monkeys (cf. Straus, 1930a), and even, as an extremely rare anomaly, in man. The tendon of the flexor digitorum brevis to the second toe of *Perodicticus*, furthermore, may be weak (W. L. S.) or even rudimentary (Forster). On the other hand, I found the remaining muscles of that digit

1936), however, is sufficient negation of such traumatic origin.

The foot musculature of an orang that I studied already has been reported upon together with data from the literature (Straus, 1930a). In general, the orang regularly possesses the full complement

of hallucal muscles, save that—in correlation with the abortive character or absence of the terminal phalanx—a long flexor tendon normally is wholly absent (Fig. 4, A). Of 23 orang-utans reported upon (Barnard; Beddard; Bischoff, 1870; Boyer; Brooks, 1888; Chapman, 1880; Church; Fick, 1895a and 1895b (2 animals); Glaesmer; Gratiolet and Alix; Hafferl; Hartmann; Hepburn; Huxley, 1864b; Langer; Michaelis; Owen; Primrose; Sonntag, 1924; C. Stewart; Straus, 1930a; Testut, 1884), this tendon was entirely lacking in 21 animals. Of the remaining two, one possessed a functionless rudiment disconnected from muscle more marked stunting implicates the corresponding digit of their hands.

In both *Nycticebus* and *Loris*, the index finger possesses three phalanges and a nail. The phalanges—especially the middle and terminal—however, are comparatively quite short, producing a stunted appearance (Fig. 5). Among primates, eight muscles normally are inserted upon the second finger, of which 6 are volar—a tendon from the flexor digitorum sublimis, one from the flexor digitorum profundus, a lumbrical, a contrahens and 2 interossei, sometimes subdivided—and 2 dorsal—a tendon from the extensor digitorum

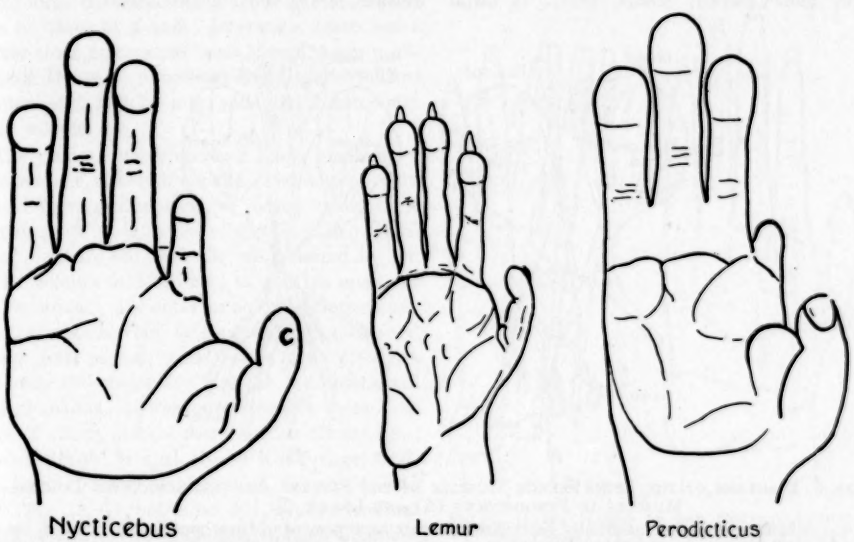

FIG. 5. RIGHT HANDS OF NYCTICEBUS, LEMUR AND PERODICTICUS. ALL AFTER MIDLO

The pincers-like form of the manus in *Nycticebus* and *Perodicticus* is not evident, for their thumbs are pictured somewhat adducted. The second finger is stunted in *Nycticebus* and a mere rudiment in *Perodicticus*, this contrasting strikingly with *Lemur*.

fibers and restricted to the hallux itself (Bischoff); the other had a hallucal tendon from the flexor digitorum tibialis (Barnard). The presumed rudiments described by Brooks and Langer fall into the doubtful category.

These hallucal characters of the orang-utan are unique among the primates and are not even suggested in any other member of the order.

HAND

Second finger

Lorisidae. The Lorisidae, as noted above, differ from other lemurs in their tendency toward dwarfing of the second toe. A similar but even

communis, and one from the extensor digitorum profundus. The flexor carpi radialis and the extensor carpi radialis longus are attached to the base of the metacarpal bone. Data for the muscles of *Nycticebus* and *Loris* are given by Murie and Mivart (1872), Kajava (1911), and Forster (1917). In these animals, the musculature of the index finger apparently is normal except for the absence of the tendon from the flexor digitorum sublimis. Default of this particular tendon has not been reported, in my knowledge, for any primate save the Lorisidae, except as an extremely rare anomaly in man (cf. Le Double).

The index finger of both *Perodicticus* and *Arc-*

tocebus is far more stunted, being truly rudimentary. Externally, that digit appears as little more than a nailless tubercle (Fig. 5). In *Perodicticus*, there are but two short phalanges, and even the metacarpal bone is abbreviated. *Arctocebus* is identical in this respect (Huxley, 1864a; Elliot, 1913). The associated musculature of *Perodicticus* is extremely deficient (Fig. 6, A). There is no long flexor tendon from either the flexor digitorum sublimis or the flexor digitorum profundus (Forster, 1933b; Van Campen; W. L. S.), no lumbrical (Kajava, 1911; W. L. S.), and no tendon from the extensor digitorum communis (Forster, 1933, a and b; Van Campen; Straus, 1941). A distal rudiment of the last-named possibly may occur, however (Straus, 1941). The other normal primate muscles are present. No data for *Arctocebus* are obtainable.

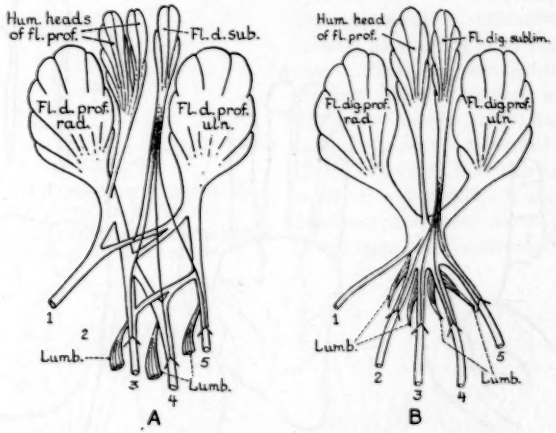

FIG. 6. DIAGRAMS OF THE LONG FLEXOR MUSCLES OF THE FINGERS AND THE ASSOCIATED LUMBRICAL MUSCLES IN PERODICTICUS (A) AND LEMUR (B)

Lemur, which possesses an essentially generalized primate arrangement of these muscles, is included for comparison with *Perodicticus*. Note that there are no long flexor tendons (from flexor digitorum sublimis and flexor digitorum profundus) and no lumbrical for the second finger of *Perodicticus*.

Thumb

The thumb is more liable to defective or incomplete development than any other primate digit. This phenomenon, moreover, has a relatively wide familial distribution, occurring in both platyrrhine —*Ateles*, *Brachyteles*—and catarrhine Anthropoidea—*Colobus*, orang-utan, chimpanzee, gorilla. It affects neither Lemuroidea nor Tarsioidea, however.

There regularly are seven muscles attached to the two phalanges and metacarpal bone of the primate thumb, 5 volar—a tendon of the flexor digitorum profundus (or its flexor pollicis longus portion), an abductor pollicis brevis, a flexor pollicis brevis superficialis, an opponens pollicis, and an adductor pollicis—and 2 dorsal—an extensor pollicis longus, either separate or as a slip of an extensor pollicis et indicis longus, and an abductor pollicis longus. A flexor pollicis brevis profundus (interosseus volaris primus of Henle) is of very irregular and variable occurrence throughout the entire order. The extensor pollicis brevis, of late evolutionary appearance, is constant only in man (Straus, 1941).

Atelinae. The coaitas or spider monkeys *Ateles* and *Brachyteles*, of the platyrrhine family Cebidae, normally lack an external thumb (Figs. 7 and 9, no. 7), hence their generic names (*ateles*, Gr., meaning "without end" or "imperfect"). Their variability respecting this feature has been thoroughly discussed by both Pocock (1925) and Schultz (1925, 1926b). An external thumb can appear in both genera (Fig. 9, no. 6), but is relatively rare in *Ateles* at least. In this genus, Schultz (1926b) found a free thumb in only 2 (in both unilaterally) of 58 animals.

Even though there be no external pollex, its rudimentary skeleton regularly is present, hidden beneath the skin. This usually comprises a small

metacarpal bone and a single, minute phalanx (Elze, Flower, Leche, Huxley, 1883). Elze (1910) believed that the phalanx actually represented a sesamoid bone, but there seems to be no doubt of its true phalangeal nature in some specimens.

When an actual external thumb occurs, this contains a metacarpal bone accompanied by either two fused phalanges (Schultz) or a single prominent phalanx (W. L. S.). In an adult *Ateles geoffroyi* (J. H. Anat. no. 351) that I dissected, a well-developed though short external thumb appeared on each hand. On the right hand, this measured 13.5 mm. from free base to tip and had a mean circumference of about 23 mm. There was no trace of a nail. Internally, there was a rather stout metacarpal bone 25 mm. long (metacarpale II was 45 mm. long) and a single phalanx 16 mm. long and 2.5 mm. wide and 2 mm. thick at its middle.

The pollical musculature of *Ateles* generally is rudimentary, although variable in its development. The following discussion is based upon three specimens of *Ateles geoffroyi* that I studied (J. H. Anat. nos. 47, 150, and 351, all collected by Dr. A. H. Schultz in Chiriqui), as well as upon the the literature. My notes for no. 150 unfortunately are incomplete. No. 351 possessed an external thumb (*vide supra*), while nos. 47 and 150 both had only the customary internal rudiments. In normal coaitas, lacking outer thumbs there is no trace of a long pollical flexor tendon (Boas; Elze; Huxley, 1864b; Meckel, cit. by Kohlbrügge, 1897, and Gruber; Senft; Wilder; W. L. S.: nos. 47 and 150) (Fig. 11, C); but in no. 351, with an external pollex, there was an undoubted though functionless distal rudiment—a thin tendinous cord that arose diffusely from the areolar tissue deep to the flexor digitorum profundus over the mid-carpal region and pursued the customary primate course along the volar surface of the thumb, to disappear in the subcutaneous connective tissue over the distal end of the phalanx (Fig. 11, B). Similarly, there normally is no long extensor tendon for the thumb (Senft, C. Stewart, W. L. S.: no. 47); yet in no. 351, the pollical phalanx received a slip from the slender tendon of an extensor pollicis et indicis longus, a muscle habitual to other platyrrhines (see Straus, 1941). A strong abductor pollicis longus always occurs (Senft, C. Stewart, Wilder, W. L. S.: nos. 47, 150, 351).

The short muscles of the thumb at times are very clearly differentiated. In no. 351, I found (1) a definite abductor pollicis brevis arising from the radial sesamoid bone of the carpus; (2) a well-developed flexor pollicis brevis superficialis, from the transverse carpal ligament; (3) a strong opponens pollicis with like ligamentous origin; (4) a thin adductor pollicis arising from the base of metacarpale III and from a raphe extending forward to the head of that bone; and (5) a slender flexor pollicis brevis profundus with origin from the ulnar border of metacarpale I. The opponens was inserted as in other primates upon the radial border of the first metacarpal bone. The four other muscles had their customary primate insertions upon the pollical phalanx, and not at all upon the metacarpal bone.

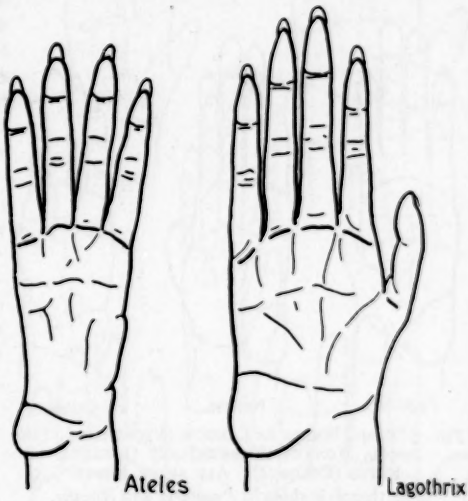

FIG. 7. RIGHT HANDS OF THE COAITA, ATELES, AND THE CLOSELY RELATED WOOLLY MONKEY, LAGOTHRIX. BOTH AFTER MIDLO

Ateles normally lacks an external thumb, whereas that digit is well-developed in *Lagothrix*.

In my two other specimens, lacking outer thumbs, the muscles were far less differentiated. Animal no. 150 exhibited a rather well-developed adductor pollicis that was inserted on the head of metacarpale I; beyond this, there were other fibers, inserted similarly, representing the remaining, undifferentiated thenar musculature. Even more rudimentary conditions obtained in no. 47, for the thenar complex appeared as one small fan-shaped mass inseparable into nameable components.

Other specimens of *Ateles*, described in the

literature, exhibited similar variability. Huxley (1864b) apparently found all of the four usual primate thenar muscles—abductor, flexor, opponens, adductor—while Leche noted all except the abductor. Only two muscles were found in the specimens of Senft (flexor and adductor) and Forster (1917, abductor and adductor). Finally, Wilder discovered only rudiments. The insertions in these animals (save possibly that of Senft) seem to have been only upon the distal part of the metacarpal bone, and not upon the phalanx.

The muscles of *Brachyteles* appear not to have been studied.

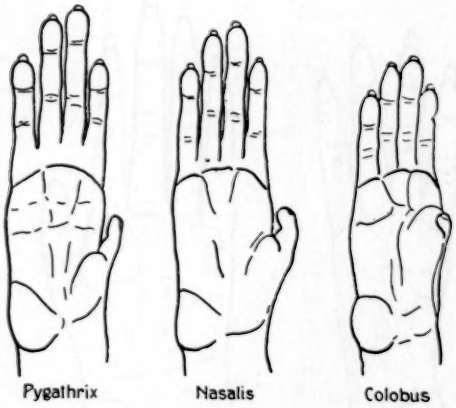

FIG. 8. RIGHT HANDS OF LANGUR (PYGATHRIX), PROBOSCIS MONKEY (NASALIS) AND GUEREZA, FETUS (COLOBUS). ALL AFTER MIDLO
The thumb is short in *Pygathrix* and *Nasalis*, rudimentary in *Colobus*.

Colobus. The guereza, *Colobus*, of the catarrhine sub-family Colobinae (*sive* Semnopithecinae), approximates the platyrrhine Atelinae in the normal possession of a rudimentary thumb (cf. Pocock, 1926; Schultz, 1924, 1926b), thus its generic name (*kolobos*, Gr., meaning "curtailed", or "incomplete", or "mutilated") (Figs. 8 and 9, nos. 1–3). Schultz has shown that while an outer

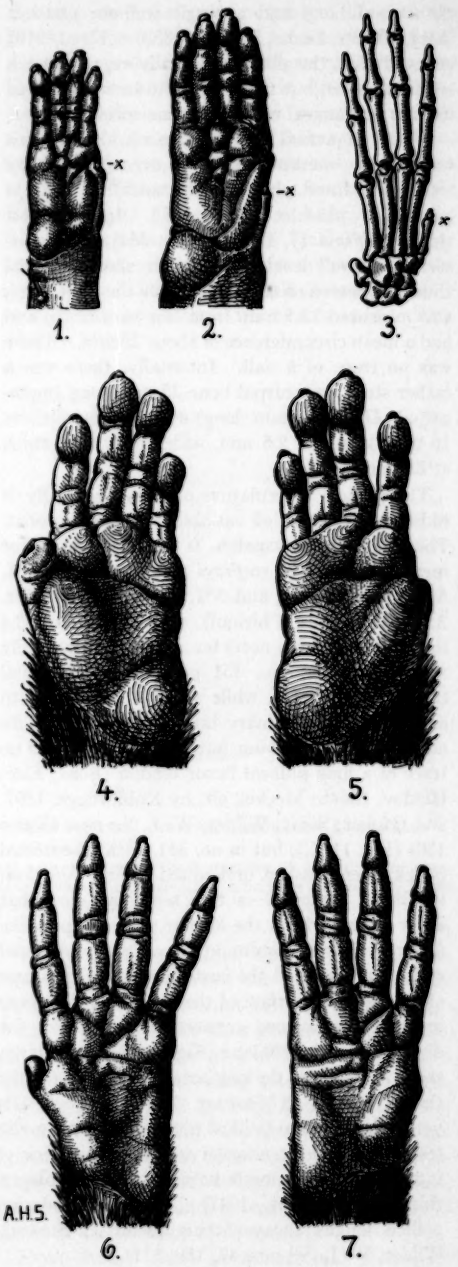

FIG. 9. DEFICIENCY OF THE THUMB IN MONKEYS
Nos. 1–3, right hands of the guereza, *Colobus*, showing rudimentary thumbs at X (1, fetus, 112 mm. sitting height; 2, fetus, 134 mm. sitting height; 3, adult lacking external thumb, skeleton only). Nos. 4 and 5, hands of a guenon, *Lasiopyga*, with external absence of right thumb. Nos. 6 and 7, infantile coaita, *Ateles*, with anomalous small external thumb on left hand. All after Schultz, 1926b.

thumb is lacking in adults or at best is but an inconsiderable nailless rudiment, it may be better developed in fetuses. Its extreme stunting, therefore, appears to be of relatively late ontogenetic occurrence (see also Johnston, 1904).

The pollical skeleton always is rudimentary (Fig. 9, no. 3). It comprises a short metacarpal bone and one small phalanx (Flower, Schultz, 1924, 1926b), but a minute second phalanx also can occur (Brooks, 1886). The thumb musculature resembles that of *Ateles*. There is no long flexor tendon (Brooks, Polak) (Fig. 11, E), nor a long extensor (Polak); the long abductor, however, is large (Polak). The short muscles are incompletely differentiated. Both Brooks and Polak noted an adductor and a mass that was inserted as both opponens (to metacarpal) and short flexor (to phalanx). The former investigator also found a short abductor, whereas the latter saw only a sheet of muscle that was inserted not upon bone but upon the thenar skin.

The langur, *Pygathrix* (*sive Semnopithecus*, *Pithecus*), and the proboscis monkey, *Nasalis* (*sive Semnopithecus nasicus*), other members of the sub-family Colobinae, possess thumbs that are comparatively short (Pocock, 1926; Midlo). These are not rudimentary or absent, however, as in *Colobus* (Fig. 8). Yet there is evidence that their musculature also can be incompletely developed. Kohlbrügge (1897) found that the long flexor tendon of the thumb could be replaced by one from the flexor digitorum sublimis (*Pygathrix*), or consist only of a distal, functionless rudiment much as in *Ateles* no. 351 (*Pygathrix*, *Nasalis*), or be completely absent (*Pygathrix*); the other pollical muscles, however, regularly were well-developed.

Truly rudimentary thumbs do not normally occur in catarrhine monkeys of the sub-family Lasiopyginae. Apparently the sole example of such a condition is the specimen of *Lasiopyga pygerythra* described by Schultz (1926b); but this (Fig. 9, no. 5), being completely anomalous, lies outside the scope of this paper.

Pongidae (*Great anthropoid apes*). On a purely dimensional basis, the thumbs of the three great anthropoid apes—orang-utan, chimpanzee, gorilla—do not fall into the category of rudimentary or stunted digits (Fig. 10). It is true that the evolutionary atrophy of the great ape thumb often has been stressed (see, e.g., Ashley-Montagu, 1931, and LeGros Clark, 1934). Schultz (1936), however, denied this allegation. He pointed out that the brevity of the pollex in the three large anthropoids is more apparent than real, being due to the great length of the rest of the hand: for when the

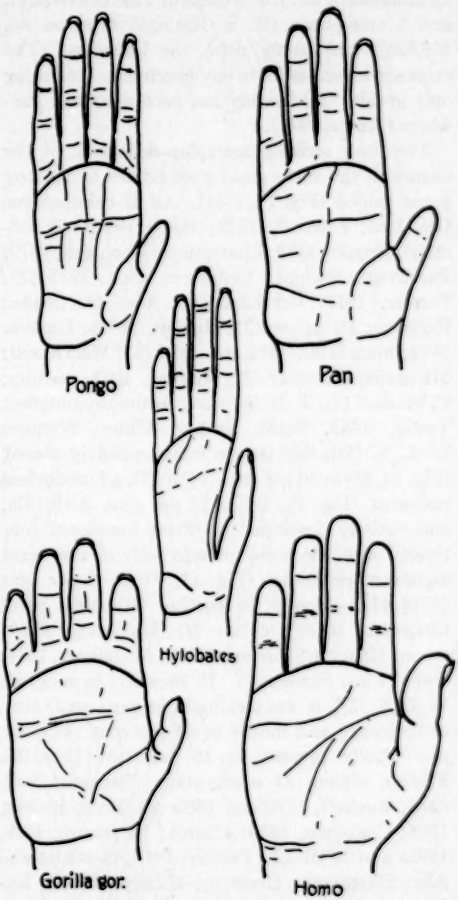

FIG. 10. RIGHT HANDS OF ORANG-UTAN (PONGO), CHIMPANZEE (PAN), GIBBON (HYLOBATES), GORILLA (GORILLA GOR.) AND MAN (HOMO). ALL AFTER MIDLO

ape thumbs are expressed in relation to body size, as represented by length of trunk, their relative lengths do not suffer significantly when compared with that of man.

When we turn to the thumb musculature, however, a stunting clearly is apparent. The follow-

ing account is based partly upon my own dissections of 5 chimpanzees (J. H. Anat. nos. 38, 156, 191, 319, 372), 2 gorillas ("H", from Museum of Comparative Zoology, Harvard University, by courtesy of Mr. H. J. Coolidge, Jr.; and "J", by kindness of Dr. J. F. Fulton of Yale University), and 1 orang-utan (U. S. National Museum no. 153,825), and partly upon the literature. The extensor musculature of my specimens (excepting only gorilla "J") already has been described elsewhere (Straus, 1941).

The most striking muscular deficiency of the thumb in the three great apes relates to its long flexor tendon (Fig. 11, F-H). Of 47 chimpanzees (Beddard; Bischoff, 1870; Boas; Broca (2 animals); Brooks, 1888; Champneys; Chapman, 1879; Duvernoy; Dwight; Embleton; Fick, 1925 (2); Forster, 1917; Gratiolet and Alix; Hartmann; Hepburn; Humphry (2); Huxley, 1864b; Kajava, 1910; Macalister, 1871 and 1874 (2); MacDowell; Michaelis; Schreiber (5); Sonntag, 1923; Sperino; C. Stewart (2); T. D. Stewart; Sutton; Symington; Testut, 1883; Traill; Vrolik; Wilder; Wyman; W. L. S. (5)), this tendon was completely absent (Fig. 11, H) in 30 per cent (14 of 47), a functionless rudiment (Fig. 11, G) in 22 per cent (10½/47), and entirely developed in direct functional continuity with the radial muscle belly of the flexor digitorum profundus (Fig. 11, F) in 48 per cent (22½/47). Among 16 gorillas (Bischoff, 1880; Chapman, 1878; Deniker (2); Duvernoy; Hartmann; Hepburn; Huxley, 1864b; Macalister, 1874; Owen; Pira; Sommer; T. D. Stewart; Symington; W. L. S. (2)), it was lacking in 31 per cent (5/16), rudimentary and inutile in 41 per cent (6½/16), and wholly present in 28 per cent (4½/16). Finally, among 27 orang-utans (Barnard; Beddard; Bischoff, 1870 and 1880 (2); Boas; Brooks, 1888; Chapman, 1880; Church; Duvernoy; Fick, 1895a and 1895b (2); Forster, 1917; Gratiolet and Alix; Hartmann; Hepburn; Huxley, 1864b; Kajava, 1910; Langer; Michaelis; Primrose; Sonntag, 1924; C. Stewart; T. D. Stewart; Sullivan and Osgood; Testut, 1883; Wood; W. L. S.), the tendon was entirely absent in 89 per cent (24/27), rudimentary and functionless in 7 per cent (2/27), and completely developed in but 4 per cent (1/27). Thus the long flexor tendon of the thumb normally is eliminated physiologically in two of the three genera of great apes (96 per cent of orangs, 72 per cent of gorillas) and is entirely without function in fully half the members of the third genus (52 per cent of chimpanzees). This is a deficiency approaching that of *Ateles* and *Colobus*. Consequently, in a majority of the great anthropoids there is no apparatus for independent flexion of the terminal phalanx of the thumb, although that bone always is developed. A weak, inefficient substitute occasionally is provided by a slender tendinous slip from one of the short thumb muscles, which has been regarded by some investigators (as Langer) as a vestige of the long flexor tendon. Such homology is extremely improbable, however, for this slip can co-exist with the undoubted long pollical tendon (as in my gorilla "H"). Even when a complete, effective long flexor tendon occurs, it almost invariably is described as extremely slender and weak, attesting to its physiological infirmity.

In my animals, the tendon was entirely suppressed in the orang-utan and two of the chimpanzees (nos. 191 and 372). In two other chimpanzees (nos. 156 and 319) and gorilla "J", there was, as in *Ateles* no. 351, a slender, distal, tendinous rudiment in all respects divorced from the fibers of the flexor digitorum profundus but attached distally to the terminal phalanx of the thumb in the manner of a normal tendon: (1) in no. 156, this rudiment arose proximally in two parts—as a thread from the fascial sheath covering the volar aspect of the index finger tendon well above the wrist, and from the dorsal aspect of the transverse carpal ligament radially; (2) in no. 319, it was prolonged from the fascia over the volar base of the first metacarpal bone; and (3) in "J", it developed from the fascia of the wrist deep to the radial part of the flexor digitorum profundus. The incomplete tendon of the fifth chimpanzee (no. 38) differed in that, while filamentous, it was connected proximally not only with the carpal fascia but also apparently with the deep long flexor tendon to the index finger; but it ended short of its expected insertion, in the fascia immediately volar to the metacarpo-phalangeal joint of the thumb. Of my gorilla "H", only the hand, severed at the wrist, was available for study. This exhibited a distinct long flexor tendon of the thumb, attached to the terminal phalanx; there seems but little doubt, moreover, in view of its form and extent, that this tendon was a functional part of the flexor digitorum profundus. The tendinous rudiments of those anthropoid apes that have been described in the literature also regularly assumed the character of distal strands

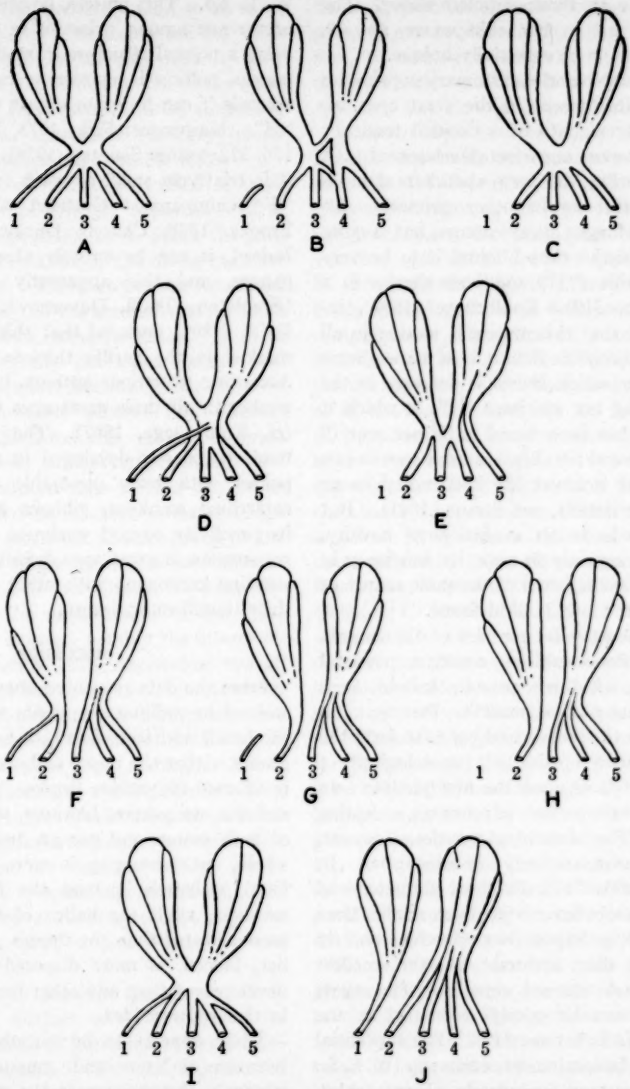

FIG. 11. DIAGRAMS OF THE DEEP LONG FLEXOR MUSCLE OF THE FINGERS (FLEXOR DIGITORUM PROFUNDUS) IN VARIOUS PRIMATES

A, *Cebus* (a representative platyrrhine monkey, for comparison with *Ateles*); B, *Ateles* no. 351; C, *Ateles* no. 47; D, *Macaca* (a representative catarrhine monkey, for comparison with *Colobus*); E, *Colobus* (from data by Polak); F-H, Great anthropoid apes (orang-utan, chimpanzee, gorilla), showing three types of arrangement common to all three animals; I, *Hylobates*; J, Man. This illustration is designed especially to show the enfeebled state or absence of the tendon to the thumb in *Ateles*, *Colobus* and the three great apes. The radial head of the muscle is to the left in each diagram, the ulnar portion to the right. The humeral heads of origin are not shown; there usually is one such head, a so-called condylo-radialis joining the radial portion of the muscle, in all of the above animals save the three great apes.

basically similar to those detailed above. The arrangement noted in my chimpanzee no. 38, however, appears to be essentially unique.

The other thumb muscles customary in primates also normally are present in the great apes, although there is evidence of a decided tendency toward weak or even imperfect development. Of the dorsal muscles, the long abductor alone is regularly powerful as in other primates. An extensor pollicis longus always occurs, but is quite variable in strength—thus I found it to be very robust in a gorilla ("J") and very slender in a chimpanzee (no. 319). Kohlbrügge (1897), indeed, concluded that this muscle is weaker in all of the great anthropoids than it is in man. Some sort of extensor pollicis brevis is not rare in the gorilla—including my specimen "J", in which it was lacking, it has been found in 53 per cent (9 of 17 animals)—and possibly has been seen in one chimpanzee; but it never has been noted in an orang-utan (for details, see Straus, 1941). But since this muscle is an evolutionary novelty, regularly occurring only in man, its deficiency in the large anthropoids is not of the same nature as that involving the long pollical flexor.

Of the five short volar muscles of the thumb, the adductor alone exhibits constant powerful development in all three genera. Indeed, it is their outstanding pollical muscle. Insertion frequently is upon the metacarpal bone (to form the so-called "adductor opponens", physiologically a misnomer) as well as upon the first phalanx—an arrangement otherwise rare in primates, excepting the gibbons. The remaining muscles, however, tend to be comparatively unsubstantial. In fact, in my gorilla "H" the short abductor and the superficial short flexor were much smaller than the corresponding hypothenar muscles; and in gorilla "J" the short abductor was the smallest of the marginal manual muscles. The short abductor also can be poorly developed in the chimpanzee (W. L. S.: no. 319). The superficial short flexor can be an almost tenuous slip (W. L. S.: gorilla "H") or even completely absent (chimpanzee: Michaelis, Duvernoy?); it often is extensively fused with the opponens in gorillas. A true, muscular, deep short flexor of the thumb (interosseus volaris primus of Henle) is rare in both the gorilla (apparently found only by Huxley, 1864b) and the chimpanzee (described by Sonntag, 1923; of doubtful homology in my no. 319), but is not uncommon in the orang-utan (Brooks, 1888; Forster, 1917; Primrose; Sullivan and Osgood; W. L. S.). This muscle, however, is of sporadic occurrence among primates in general, possibly being a normal structure in man alone. The opponens pollicis is extremely variable. In some animals it can be quite robust (gorilla: W. L. S. "H"; chimpanzee: Fick, 1925, W. L. S. nos. 38, 156, 372; orang: Sonntag, 1924), whereas in others it is relatively small or weak (gorilla: W. L. S.: "J"; chimpanzee: Gratiolet and Alix; orang: Brooks, 1888, Church, Duckworth, W. L. S.). Indeed, it can be entirely absent in the chimpanzee, and this apparently not infrequently (Embleton, Traill, Duvernoy?, Forster, 1917?). Keith (1899) declared that this muscle is better marked in the gorilla than in the chimpanzee. According to various authors, it is inclined to be weaker in all three great apes than it is in man (cf. Kohlbrügge, 1897). The opponens pollicis tends to be well-developed in all other Anthropoidea with truly opposable thumbs, namely, catarrhine monkeys, gibbons and man. Hence its proclivity toward weakness or even complete suppression in great apes definitely is a species of stunting consonant with other characteristics of their thumb musculature.

DISCUSSION

From the data presented above, it is clear that stunted or rudimentary digits normally occur on the hands and feet of certain primates. In some genera, either the upper or lower extremity alone is affected in various degrees. In the Lorisidae and the orang-utan, however, the identical digits of both manus and pes are implicated. On the whole, such dwarfing is more advanced in the hand, although in man the fifth toe alone is involved, while the hallux of the orang is even more arrested than the thumb. The latter member, indeed, is more disposed toward defective development than any other finger or toe, at least in the Anthropoidea.

There appears to be no absolute correlation between skeleton and musculature. In some instances the skeleton is the more severely curtailed (fifth toe of man, hallux of orang), in others the musculature (thumbs of great apes and of *Pygathrix* and *Nasalis*), while in still others both bones and muscles show approximately the same degrees of abridgment (second toes and second fingers of Lorisidae, thumbs of *Ateles* and *Colobus*). The nail is absent only when the skeleton is extremely abbreviated.

The long, extrinsic muscles of the affected digit,

whether finger or toe, definitely tend to be more defective than the short, intrinsic muscles. This is especially apparent when the digit is truly rudimentary, as in the hallux of the orang-utan, the index finger of *Perodicticus*, and the thumbs of *Ateles* and *Colobus*. The same tendency, moreover, also is evident in less reduced digits.

The significance of normally dwarfed or rudimentary digits is not entirely apparent. What factors might be operating to so affect the fifth toe of man and the hallux of the orang-utan are a complete mystery. There is a possible functional correlation, however, for the arrested second digits of both hand and foot of the Lorisidae. In these animals, the powerfully developed thumb and hallux both are set apart from the other digits so as to produce veritable pincers (see Forster, 1933b, who has discussed this subject in great detail). The normal abduction of thumb and hallux is so pronounced that neither can be as completely adducted as in other primates (Figs. 1 and 2). Of the ulnar (or fibular) prong of the pincers, the fourth finger (or toe) is predominant and is the podial axis—as witness its relatively great length and the arrangement of the short manual (or pedal) muscles, notably the interossei, about it. Incidentally, this disposition toward predominance of the fourth digit and an associated grouping of the musculature is a distinct lemurine feature more or less characteristic of the Lemuroidea as a whole (see Straus, 1930, a and b). Elimination or even reduction of the digits intervening between it and the first would tend to increase the span of the pincers, but scarcely, it would seem, without decreasing the strength of its grasp. In this connection, it seems significant that Hill (1936) has indicated a dwarfing of not only the second digits but also of the third in some Lorisidae.

When we come to consider the thumb, there appears to be a distinct relation between its stunting and the habit of bimanual arboreal locomotion or "brachiation." For the chimpanzee and orang-utan, the Colobinae (see Pocock, 1926), and the Atelinae all are accomplished brachiators. The gorilla, chiefly because of the limitations imposed by its great adult weight, is a brachiator only in immaturity; but there is little doubt of its definite brachiating ancestry. Furthermore, it will be obvious to those who have observed living primates that brachiation fundamentally is dependent upon only the four ulnar fingers. The thumb not only is not involved, but actually can be an incumbrance, for a forceps- or pincers-like grasp is not employed. It is not illogical, therefore, to assume a correlation between dwarfing of the thumb and the habit of brachiation in Atelinae, Colobinae and great anthropoid apes.

It nevertheless is certain that a stunted pollex is not an inevitable accompaniment of a brachiating method of locomotion. For the Hylobatidae—gibbons and siamang—are extraordinary and habitual brachiators, far surpassing the great apes, yet they give no evidence of pollical deficiency. In these animals (Fig. 10), the thumb is of relatively great length, even being somewhat longer, comparatively, than that of man, especially in *Hylobates* (Schultz, 1936). Its musculature, although uniquely specialized in some respects—as in the marked tendency for its short muscles to be powerfully inserted upon the metacarpal bone—in no sense is defective or weak. Thus, for example, a well-developed long flexor tendon of the thumb was present and completely functional in all of 13 specimens that have been reported upon (Bischoff, 1870; Chapman, 1901; Deniker; Hartmann; Hepburn; Huxley, 1864b; Kohlbrügge, 1890 (3); C. Stewart; W. L. S. (3)). Perhaps this compatibility of a well-developed thumb with constant brachiation can be traced to the mode of bimanual locomotion peculiar to gibbons and siamangs. Their thumb is separated from the other fingers by a great cleft that uniquely extends far proximal to the first metacarpo-phalangeal joint (Fig. 10); hence the pollex, despite its great length, easily can be bent across the proximal palm, where it is of no hindrance in brachiation. Or, on occasion, the thumb can be tucked away, so as virtually to be flush with the palm, in the peculiar groove along the radial side of the hand that is found only in Hylobatidae (also see Pocock, 1926). These are not the only peculiarities of gibbons that probably are related to their type of brachiation. For they possess certain muscular specializations of the upper extremity not encountered in the three great anthropoids, *Colobus* and *Ateles*. As indicated in an earlier paper (Straus, 1940), the term "brachiation" is a broad one, for the mode of bimanual arboreal locomotion is not precisely identical in all "brachiators," and adaptations to such form of progression have been made in different ways.

From an evolutionary aspect, the underdevelopment and functional weakness of the thumb in the three great apes is a regression. The comparatively feeble nature of this digit will be well

appreciated by those who have had experience with living anthropoids. On the other hand, the thumb relatively is much stronger in most catarrhine monkeys (save the Colobinae), Hylobatidae and man. In fact, the remarkable development of the human thumb, especially of its associated musculature, contrasts strikingly with the conditions in the great anthropoid apes. There is not the slightest evidence of an evolutionary degeneration in the structure of man's thumb. Thus, functional default of its long flexor tendon, so common in the great apes, is among the rarest of all human muscular anomalies. To my knowledge, it has been reported for but five bodies, all white—by Gegenbaur (1861), Wagstaffe (1872), Gruber (1875), Chudzinski (1881), and Fromont (1895). Of these, the tendon was entirely lacking in two, present in the other three in the form of a distal rudiment as in many examples of the giant anthropoids. At least two of these bodies, however, possessed other, associated muscular anomalies and even serious defects, while the third was that of a microcephalic infant. Hence these instances appear to have no more phylogenetic significance than other anomalies of a similar nature. The constancy of the long flexor tendon of the human thumb is indicated by the fact that both Testut (1883) and Le Double (1897) found it always present in over 200 and in 327 French bodies, respectively. Furthermore, I myself never have noted its absence nor deficiency, nor have I ever been apprised of such condition during my fifteen years in this laboratory, although fully 300 cadavers, chiefly Negro, have passed through the dissecting rooms during that time.

Thus it is clear that a comparative study of the thumb yields additional evidence in support of the view, expressed in previous papers (Straus, 1940, 1941), that man did not pass through a pronounced "brachiating" stage in his phylogeny: for the human thumb essentially is of a generalized structure, completely lacking not only the defective qualities found in the pollices of the great apes and most other brachiators but also the peculiar specializations relating to the thumbs of the Hylobatidae. This evidence likewise presents a major obstacle for those who believe that man has other than a very remote relationship to the great apes.

SUMMARY

The Primates in general are characterized by five well-developed digits on both manus and pes. A few forms, nevertheless, normally possess one or more stunted or rudimentary digits. These forms include the lorisine lemurs (second finger and second toe), the platyrrhine Atelinae (thumb), the catarrhine Colobinae, particularly *Colobus* (thumb), the orang-utan (thumb and hallux), the chimpanzee (thumb), the gorilla (thumb), and man (fifth toe).

There appears to be no absolute correlation between bones and muscles. In some rudimentary digits the skeleton is the more severely affected (fifth toe of man, hallux of orang), in others the musculature (thumbs of great apes and of certain Colobinae), while in still others both of these structures exhibit essentially similar degrees of curtailment (second fingers and toes of Lorisidae, thumbs of *Ateles* and *Colobus*). The long, extrinsic muscles of the affected digit distinctly tend to be more defective than the short, intrinsic muscles.

The significance of some normally rudimentary digits (fifth toe of man, hallux of orang) is entirely obscure. The arrested digits of the Lorisidae, however, seem to be related to the peculiar pincers-like grasp of their hands and feet, in which the first and fourth are the dominant digits. As for a rudimentary or stunted thumb, this apparently can be correlated with the habit of "brachiation." This mode of locomotion, nevertheless, is not necessarily accompanied by a poorly-developed thumb, as witness the Hylobatidae. These animals clearly are adapted to a brachiating life in a manner quite different from that of Atelinae, Colobinae, and great apes.

The evidence produced by a comparative study of the thumb supports not only the view that man's phylogeny did not include a pronounced brachiating stage, but also that view which denies man other than very remote relationship to the great anthropoid apes.

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ON THE INTERPRETATION OF RADIATION EXPERIMENTS IN GENETICS

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AN INTERPRETATION of the X-ray production of mutations has been formulated on the basis of the "hit theory" or "target hypothesis" (see especially Timofeeff-Ressovski, 1937; further developments by Lea, 1940). The theory assumes that a "gene mutation" is produced by ionizing radiations whenever some primary phenomenon, a "hit," occurs within a certain region of space called the "target." Although the theory successfully accounts for several important experimental facts, it is subject to criticism. Some progress has already been made towards less specific but also less restrictive interpretations of the experimental data (e.g. Muller, 1940). It is the purpose of the present paper to consider again the implications of the experimental data in an effort to show which results of the hit theory are independent of its binding assumptions. Certain types of mutations, for instance the "gene mutations," have been frequently considered in the literature on the hit theory as well defined and homogenous classes of phenomena. The same procedure will be followed for simplicity in this paper, while its possible criticism is considered in another paper (Fano, 1941).

1. The interpretation according to the hit theory

Ionizations distributed according to probability laws have generally been considered as the primary physical phenomena leading to the random production of mutations. The target might be identical with the gene, but may conceivably be larger or smaller; it might consist of many parts.

On the basis of random distribution of ionizations within irradiated matter, the probability of producing an ionization within the target, and hence the frequency of mutations, must be proportional to the total number of ionizations produced. The following well-known results of X-ray experiments can then easily be explained:

(a) The number of gene mutations produced in N_0 *Drosophila* sperms by the dose D of X- or γ-rays is proportional to both N_0 and D:

$$N = \text{const.}\ N_0\, D. \qquad (1)$$

(b) The constant is independent of variations in wave-length and in the time distribution of irradiation, if the radiation dosage is measured as any equivalent of the ionization produced per unit volume of matter.

The frequency of ionizations within the target is given by the size of the target times the number of ionizations per unit volume. Therefore, the size of the target can be calculated according to the hit theory from the experimental value of the constant in formula (1). In experiments on single mutations the target has been found to be about 1 $m\mu$ in size, that is to contain about 1000 atoms.

The efficiency of radiation should be reduced by an excessive density of ionizations. The ionizations produced by radiations are not distributed fully at random but lie along the path of "ionizing particles." When the distance of successive ionizations is smaller than the thickness of the target, a single ionizing particle may produce several ionizations within the target. The actions of these ionizations do not add up, because each one of them is sufficient to produce a mutation, and thus there arises a waste of ionizations. Hence the number of mutations produced by a given number of ionizations should be smaller than in the case of radiation with a low density of ionization. This phenomenon is called "saturation effect."

Investigations with soft X-rays producing densely ionizing photoelectrons failed to show any saturation effect on gene mutations in *Drosophila* (Wilhelmy, Zimmer and Timofeeff-Ressovski, 1936; Fricke and Demerec, 1937). Jordan (1938a) pointed out that Wyckoff's data (1930) on the killing of *Escherichia coli* by soft X-rays show the beginning of a saturation effect. The thickness of

the target for the killing of *E. coli* should thus be approximately equal to the average distance of ionizations in the experiment ($\simeq 6$ mμ). Zimmer and Timofeeff-Ressovski (1938) found a saturation effect in the production of sex-linked lethals in *Drosophila melanogaster* by neutron rays, which act through densely ionizing protons. The production of lethals by neutrons follows formula (1) but the constant factor is 1.6 times smaller than in the case of X-rays. Investigations by Gray and Read, 1939, confirm the reliability of the dosimetry used by Zimmer, 1938, and thus support the results of the neutron experiment.

A quantitative theory of the saturation effect was developed by Lea (1940) who calculated the dependence of the constant in formula (1) upon the ion density, in the case of a spherical target. Lea assumed that the target for sex-linked lethals consists of a number of spherical targets each of them corresponding to a locus of the X-chromosome where the lethal may occur. The total volume of the targets is given by the X-ray experiments; the average thickness of the single "targets" is given by the neutron experiment and the theory of the saturation effect. Hence Lea deduced that the target for all sex-linked lethals consists of about 1860 spheres. This number represents also the total number of genes in the X-chromosome, if the further assumption is made that each gene is capable of exhibiting a lethal mutation. The single spherical targets are found to be of the same order of magnitude as the targets for individual visible mutations of single genes; this coincidence lends further support to the theory. Thus Lea's estimate of the "number of genes" might also be deduced as the ratio of the frequency of all sex-linked lethals to the frequency of individual mutations.

2. *Discussion on the size of the target*

The broadest principle of the hit theory is that the statistical law:

$$N = kN_0D, \qquad (k = \text{constant}), \qquad (1)$$

is determined by inherent characteristics of the biophysical process. (N is the average number of mutations, N_0 the number of irradiated sperms, D the dose. Which class of mutations is considered is immaterial here.) While the constant k is defined experimentally as the average frequency of mutations produced by unit dose, according to the hit theory it must have some particular theoretical meaning. An initial set of assumptions which have been widely accepted is then required:

(a) The observed discontinuous mutation phenomena correspond to an actual "all or none" primary phenomenon in the genetic material.

(b) The genetic material of different sperms may be considered as identical.

(c) The experimental law (1) is valid beyond the present stage of investigation, i.e. it is valid down to any low dosage and there is no dependence whatsoever on the time distribution of irradiation.

If (a), (b), and (c) are fulfilled, k may be interpreted as the *mathematical probability* that one unit radiation dose produces a mutation in any particular sperm. The choice of the unit of dosage is thus far arbitrary but different numerical values of k correspond to different units.

It is interesting to consider units of dosage emphasizing the discontinuous nature of radiation. The unit of dosage may be related to a "flow" of radiation (for example the passage of one X-ray quantum or of one particle per sq. cm.) or to the production of secondary phenomena within matter (for example the production of one ionization or of one secondary electron per cc.). In the first case the probability k is equal to the area of a surface which is crossed by a quantum as frequently as a mutation is produced, in the second case it is equal to the volume of a region within which one secondary phenomenon is produced with the same frequency. An area or volume equal to k will then represent the probability of production of a mutation and is accordingly called an "effective cross section" or an "effective volume." In order to follow the familiar procedure, the production of one ionization per cc. at a random position within matter will be assumed as a unit of dosage throughout this section. This unit is a definite fraction,

$$1/(2 \times 10^{12})$$

of the roentgen unit. The reasons for this choice and its actual significance will be discussed in the following sections. Then k shall represent the "effective volume" for the production of a mutation (of the class under consideration) by an ionization and will be indicated by τ.

An experiment may be considered as a numerical example, in which 591 ClB tests for sex-linked lethals were carried out among the offspring of *Drosophila* males X-rayed with 4500 r and 72 lethals were found. The following figures must

then be entered in formula (1): $N = 72, N_0 = 591$, $D = 4500 \times 2 \times 10^{12}$ ionizations/cm.^{3}; hence

$$\tau = k = \frac{72}{591 \times 4500 \times 2 \times 10^{12}} \approx 10^{-17} \text{ cm.}^3$$

The hit theory further assumes usually that the "effective volume" τ defined above is not simply a probability, i.e. a mathematical quantity, but that it measures *the actual volume of a target*. This assumption goes far beyond the preceding ones. It does not seem necessarily correct to assume that τ measures an actual volume. On one hand there certainly is a relationship between τ and an actual volume, because an ionization can be effective only if it occurs sufficiently close to the place of production of a mutation, i.e. within some specific "sensitive region." This relationship may be called a *spatial probability factor*. There is, however, another factor affecting the value of τ, which has been taken into consideration only recently (e.g. Jordan, 1939; Muller, 1940) and which may be called the *physical probability factor*. Whenever an atomic system absorbs an amount of energy, for instance through an ionization, the outcome of the phenomenon is not completely determined. Thus a free excited atom can emit alternately light of different colors; atomic mechanics can determine only the relative probability of different emissions. Whenever a molecule is supplied with the activation energy required for a certain reaction, the reaction does not necessarily occur; its probability is frequently called "quantum efficiency" and it may approach one, or it may be very small. Only a detailed knowledge of the reaction and of the structure of the atomic system which is affected can afford an *a priori* evaluation of the physical probability factor. It is quite possible, moreover, that there is no immediate strictly physical connection between the physical phenomena produced by radiation and the change of the genetic material which is a mutation. Ionizations or analogous phenomena might act primarily as a perturbation to the biochemical system of which the genetical material is a part; a further chain of physico-chemical processes might or might not, according to chance, lead to a mutation (see, e.g. Fricke and Demerec, 1937).

The "effective volume" τ should then be split into a factor V representing the spatial factor, i.e. the actual volume of a sensitive region, and a physical factor p, i.e. the average probability that an ionization occurring within the sensitive region produces a mutation ($\tau = pV$). No satisfactory method has yet been developed to evaluate even the order of magnitude of p and V separately. The only present possibility of evaluating directly the size of the "sensitive volume" might be offered by the saturation effect (Section 4). A purely physical approach to the same problem is to consider the maximum distance of propagation of the physical atomic actions arising from an ionization as the radius of the sensitive region; the sensitive region would thus be introduced as a theoretical physical quantity. It is difficult, however, to draw conclusions along this line without any detailed knowledge of the atomic structure of the matter involved. When special circumstances favor, for instance, the existence of metastable atomic states and the transport of excitation energy or the occurrence of self-multiplicating chain phenomena, a phenomenon starting from a single atom may spread over distances of even microscopical order. Therefore, the argument outlined by Delbruck (1940) that the linear dimensions of the "effective volume" for the production of gene mutations (≈ 1 mμ) are already so large that the sensitive region cannot reasonably be still much larger, might not be very conclusive.

Arbitrary neglect of the physical factor (i.e. assuming $p = 1$) leads to the acceptance as a correct estimate of the size of the sensitive region of what actually is its minimum value. In fact, the physical factor reduces the average efficiency of radiation. The more important is the physical factor (i.e. the smaller is p), the larger is the ratio of the size of the sensitive region to the measured "effective volume" τ.

In conclusion, the broadest interpretation of the hit theory based on the assumptions (a), (b), and (c) given above leads to the definition of an effective volume τ which is a probability. (The "effective volume" as used here corresponds to the "sensitive volume" as used by Muller, 1940, and to the "action volume" as used by Wollman *et al.*, 1940, while Muller's "potential sensitive volume" corresponds to the volume V of the sensitive region.) Although this probability certainly involves a factor related to the size of a sensitive region, there is not much evidence to assume further that this is the only important factor, so that one might identify the "effective volume" τ with the size of a target or sensitive volume.

3. *The problem of the "nature of the hit"*

Attempts have been made to identify the "hit" with some one of the physical phenomena produced by radiation within matter. The most usual method which has been applied mainly to the X-ray production of gene mutations (e.g. Timofeeff-Ressovski, 1937) will be outlined first. Three possible cases are considered, namely that the "hit" consists of:

(a) Absorption or scattering of an X-ray quantum, and consequent production of a secondary electron, within a target.

(b) Passage of a "secondary electron" across a target.

(c) Production of an ionization by a secondary electron within a target.

Neglecting the physical probability factor, the size of the target is equal to the constant k in formula (1). The proper choice of the unit of the X-ray dosage is: in case (a), the production of one secondary electron per cc. of matter; in case (b), the flow of one secondary electron per sq. cm. within matter; in case (c), the production of one ionization per cc. of matter; this last unit is essentially a submultiple of the roentgen unit. The ratios among these three units, and hence the ratios among the corresponding evaluations of the target, can be determined with good approximation on the basis of physical data and depend on the wave-length of the X-rays. Experiments with different wave-lengths, where no saturation effect is observed, show that the size of the target is independent of the wave-length in case (c) but variable in the cases (a) and (b). Since the target cannot actually vary, only (c) is acceptable.

This procedure is a device by which to select one from among different working models. Successful comparison with experiments may, however, lead the working model (c) to be considered as wholly successful, even though only a part of its features is involved in the comparison. It will be shown that the results of the experiments with X-rays of different wave-lengths do not actually support the model representing a "hit" as an ionization within a target, but they can be interpreted *independently of the hit theory*.

The quantity k in the formula (1) is essentially a measure of the efficiency of a unit of radiation. An experimental result which is interpreted by the hit theory as a variation of the size of the target actually means a variation of efficiency, since it shows that an equal number of radiation units produces different biological effects in different cases. Thus the experiments on the production of gene mutations with X-rays of different wave-lengths show that the efficiency of each ionization produced by X-rays is constant. The *distribution* of the ionizations is *immaterial* and the biological action depends only on the *total number* of ions produced by all the secondary electrons.

One may then conclude that (within the limits of these experiments) the physical action of a secondary electron is not biologically effective as a whole. Different ionizations produced by the same or by different electrons do not participate as a cooperative team to the biological action, but their actions are merely superimposed. Each ionization is somehow biologically effective by itself and may be considered *as an independent cause* of the biological action. This does not necessarily mean that a single ionization is sufficient to produce an appreciable biological change, but that it is able to contribute somehow by itself to this action without any need for immediate cooperation by other phenomena, or else, that it may suitably be considered as a "unit of action." This is an extract of the concept of "hit" excluding those elements of this concept, which correspond only to working models.

Thus, although secondary electrons are themselves in a way the cause of mutation, their action can be analyzed showing that single subunits of its physical action (the ionizations) may be considered as a *nearer cause* of the biological action. The procedure which is usually intended to determine the "nature of the hit" may be considered as an analysis of the secondary physical action of radiation aiming at identifying the nearest cause of its biological action. A pattern of analysis along this line, following step by step the chain of secondary phenomena, is shown below in Section 5.

It is not quite correct to focus attention only on ionization phenomena. Atomic excitation phenomena should also be considered, in which energy is delivered to a single atom without removing any one of its electrons. Furthermore, one must distinguish between the atomic phenomena produced directly by photo- or Compton-electrons and the phenomena produced indirectly through the action of the tertiary electrons ejected whenever an ionization occurs. The total number of ionizations is, however, a fair index of the whole of the atomic

phenomena produced by radiation, since the relative frequency of different phenomena and the mean amount of energy distributed to matter "per ionization" are widely independent of the quality of radiation. Further details on this subject will be given in Section 5.

4. *The saturation effect*

Biological actions do not always depend only on the number of ionizations produced by radiation, as the production of mutation by X-rays does, but they sometimes depend also on the density along the tracks of ionizing particles. Cases are known in which the biological effectiveness of ionizations increases when the ion density along the tracks of the ionizing particles is increased and cases are also known in which the effectiveness decreases under the same conditions. The first phenomenon has been sometimes called "concentration effect"; it clearly must occur when single ionizations are not very effective but their effectiveness is improved by the cooperative action which is possible at high concentration.

The opposite saturation effect, i.e. a loss of effectiveness at increasing concentration of ions, has already been discussed from the standpoint of the hit theory in Section 1, but will be further analyzed here, independently of the hit theory. The average biological effectiveness of a flow of ionizing particles is represented by the constant k of formula (1) when the dose is measured as a flow of particles per unit area within matter; k is then an "effective cross section," (see Section 2). The io density along the track of the particles is simply a measure of the energy absorbed by matter (see above and Section 5). When the ion density is small and there is no saturation effect, as in the X-ray production of mutations, the effectiveness of the flow of particles is proportional to the energy delivered to matter per unit path. This is a quite understandable result without any reference to the hit theory. As the ion density increases, however, the effectiveness cannot be expected to remain proportional to the energy absorption so as to increase beyond any limit, because particles passing too far away from the genetic material are not expected ever to be effective, no matter how concentrated their physical action may be. At best, if the ion density were so large that the action of ionizing particles is smashing and decisive, all those, but only those, particles passing close enough to the genetic material would be effective. (The "effect" means here the occurrence of one among all the possible alternative changes, as, e.g. the mutation of a gene to one among all its allels.) The extreme case of particles which are effective whenever smashing across some sensitive region does not seem to have yet been observed but would afford a concrete application of the concept of "hit." In this case the effectiveness of ionizing particles would be fully "saturated" and would not increase any further with increasing ion density: its constant value would yield a direct measurement of the average cross section of the sensitive region. These considerations assume merely that the concept of a sensitive region is correct to some extent.

The "effective volume" τ defined in Section 2 is the ratio of the effectiveness of ionizing particles to the ion density along their paths. Thus τ is constant as long as the effectiveness is proportional to the ion density (no saturation). At full saturation, on the contrary, the effectiveness is constant and τ is proportional to the ion density.

In any practical case the effectiveness of ionizing particles is not known to have reached its maximum value and it yields only a minimum estimate of the size of the sensitive region. Such estimate is carried out here as an example, accurate within an order of magnitude, for the production of sex-linked lethals in *Drosophila melanogaster*. The "effective volume" τ is of the order of 10^{-17} cm.,[3] both for X-rays and neutrons. In the neutron experiments the recoil protons induce approximately 10^7 ionizations per cm. path; hence the flow of one recoil proton per cm.^{2} corresponds to 10^7 ionizations per cm.^{3} Accordingly, the value of k which can be called "effective cross section" must be 10^7 times larger than τ:

$$10^7 \times 10^{-17} = 10^{-10} \text{ cm.}^2$$

The next objective is to investigate the relationship between the effectiveness and the ion density when the ion density is neither very low nor very large. Its qualitative behavior is indicated by the broken line in Fig. 1. The two short segments at the beginning and at the end of this curve, which are indicated by a solid line, represent the results stated above, namely: (a) the effectiveness is expected to be proportional to the energy absorption when the energy absorption is very small, and (b) the effectiveness should not exceed a maximum limit which is determined by

the size of a sensitive region and which might be attained only at very high ion density. If it were possible to represent the whole curve by a theoretical formula involving a number of unknown parameters, one could determine the value of the parameters by fitting a sufficient number of experimental points and thus determine the maximum effectiveness and hence the size of the sensitive region.

If all the individual particles which cross the sensitive region delivered the same amount of energy within it and if all parts of the sensitive region were equally sensitive, one might expect the saturation effect to step in sharply at a certain ion density, as indicated by the dotted line in the figure. If, on the contrary, the energy delivered by different particles, or the local sensitivity, is variable, saturation must step in gradually: At any given value of the mean ion density the physical action of some particles which by chance deliver more energy, or which deliver it at more effective points, may already be excessively crowded and thus, on the average, less effective, while the effectiveness of other particles is not yet reduced, being still sufficiently small. One may imagine that the particles are classified into many different groups with homogeneous effectiveness, each of which is affected by saturation abruptly—as indicated by the dotted line in Fig. 1—but at a different value of the mean ion density. The final relationship between the average effectiveness of all particles and the mean ion density is then represented by an average of dotted lines with variable scale of abscissae. *The larger is the variability, the more will the final (broken) curve depart from the shape of the dotted line.*

There are several factors of variability. First, the lengths of the paths of the ionizing particles across the sensitive region cannot be all equal, depending on whether the crossing is central or not. This factor is variously important according to the shape of the sensitive region; it is least important in the case of a spherical shape (this shape is most compact because its surface is a minimum for a given volume). Second, there are fluctuations of the energy actually delivered by ionizing particles within paths of equal length. This again is due to various causes: (a) An ionizing particle undergoes discontinuous energy losses producing ionizations and excitations distributed at random along its track; the number of energy losses within the path across the sensitive region may vary strongly unless this path is much longer than the average distance between successive energy losses (the hit theory has been mainly concerned with this factor). (b) The amount of energy lost in any single process is also highly variable. (c) Beside the random variations considered under (a) and (b), the amount of energy lost and the ion density undergo a systematic increase along the path of an ionizing particle which is progressively slowed down; moreover, even the initial velocity of the particles is not uniform, when they originate as Compton-electrons or recoil protons. Third, there may be variability of sensitivity in different parts of the sensitive region; this variability might even make the concept itself of a sensitive region hardly significant, if it is very smoothly graded.

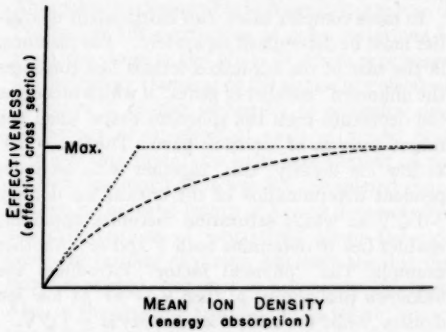

FIG. 1. GRAPHICAL REPRESENTATION OF THE SATURATION EFFECT
(See discussion in the text)

The theory developed by Lea (1940) takes into account only that part of the variability factors which is most easily accessible to quantitative investigation, namely: (a) the variability of the length of the path across the sensitive region and this only for the extreme case of a spherical shape, (b) the variability of the number of energy losses within any given length of path, without any reference to the amount of energy. Neglect of the other variability factors makes Lea's curve depart too little from the shape of the dotted line in Fig. 1. Hence any evaluation of the upper limit of the effectiveness, that is, of the size of the sensitive region, which is based on fitting Lea's curve to experimental results is bound to give a result which is *certainly smaller* than the correct one. The assumptions made by Lea do not correspond to the choice of an average but of an extreme case. The

quantitative accuracy of Lea's curve has not yet been evaluated.

Lea's neglect of the "physical probability factor" does not affect the shape of his curve: The course of saturation is the same, whether, for example, an ionization has the probability 1 or only 1/10 of producing a mutation; in the last case, however, the ion density must be ten times larger to produce the same saturation effect.

According to Lea's theory, the knowledge of the "effective volume" τ for a single value of the ion density is sufficient to determine its value at any other density. Qualitatively: Calling V the volume of the sensitive region, τ must be equal to V at low ion density and then become smaller when the average distance between successive ionizations is $\approx \sqrt[3]{V}$.

In more complex cases, two independent quantities must be determined separately. For instance, in the case of the sex-linked lethals Lea considers the unknown "number of genes" n which measures the departure from the spherical shape when the target consists of separate parts: Then $\tau = nV$ at low ion density; this, together with an independent determination of the critical ion density $\sim 1\sqrt[3]{V}$ at which saturation becomes apparent, enables Lea to determine both V and n. Another example: The "physical factor" introduces the unknown probability p; then $\tau = pV$ at low ion density, while the critical ion density is $\approx 1\sqrt[3]{V}$.

When, however, the departure from the spherical shape and the "physical factor" and, furthermore, the other variability factors listed above are all considered at the same time, the dependence of τ on the ion density becomes so complex that the quantities like V and p cannot be easily determined.

Thus there does not seem to be much conclusive evidence supporting Lea's detailed interpretation of the saturation effect on sex-linked lethals in *Drosophila*. It is possible, however, to apply the saturation effect to test whether the sex-linked lethals consist of alternate independent mutations at different loci and whether each one of these mutations is analogous to the individual phenotypically detected mutations. If it is so, the saturation effect should affect equally the production of all the lethals and of the individual phenotypical mutations. Then the ratio of the frequency of all sex-linked lethals to the average frequency of individual mutations should be approximately independent of the ion density and represent approximately the number of possible different lethals in the X-chromosome.

5. *Investigation of the "nearest cause" of a biological action and remarks on the physical action of X-rays*

As a first step of analysis it must be checked whether single X-ray quanta can be considered as an "independent cause" of any biological effect under consideration, for example of mutations, in the sense considered in Section 3. This can be done by testing experimentally that the distribution in time of the radiation quanta has no bearing on their effect.

Secondary electrons must be considered in a successive step. Soft X-ray quanta interact primarily with matter only through the production of a single photo-electron, whereby they disappear; thus the action of a quantum can be identified with that of a photo-electron. Hard X-ray quanta produce many secondary Compton-electrons through successive scattering processes; these processes occur, however, on the average, so far apart as compared to cytological dimensions, that immediate cooperation between "brother" Compton-electrons can be disregarded. Hence in any case individual secondary fast electrons can be considered as "independent cause" of the biological effect.

Fast electrons, as well as all other fast charged particles, traversing matter undergo a large number of energy losses in which a small fraction of their kinetic energy is transferred to individual electrons within matter. These energy transfers from fast electrons, henceforth called "energy transfers," are governed by important rather simple laws. The amount of energy transferred in a single energy transfer is highly variable and averages ≈ 30 electron-volts. Small energy transfers are much more frequent than large ones. If the energy transfer exceeds a limit characteristic of the kind of matter, of the order of ten electron-volts, the electron absorbing this energy can abandon the atom or molecule to which it was previously bound (ionization). If the energy transfer is smaller, a simple electronic excitation occurs. *The relative frequency of the various kinds of energy transfers is approximately independent of the energy of the impinging electron* (and depends very little on whether the impinging particle is an electron or an heavy particle, provided that they have the same charge and velocity). The total frequency of energy transfers

along the path of a fast electron, on the contrary, is *approximately inversely proportional to the energy of the electron.* Therefore, a change of the wave-length of the X-rays, which means a change of the energy of the quanta and hence a change of the energy of the secondary electrons, does not affect appreciably the quality of the energy transfers but only their density along the electron tracks. The total amount of energy loss and the number of ionizations produced are proportional to the number of energy transfers; thus the measurements of X-ray dosages in roentgen units may also be expressed as a "number of energy transfers per unit volume." The frequency of production of gene mutations by X-rays is then proportional to the number of energy transfers independently of their density along the tracks of secondary electrons. Therefore, single energy transfers can be considered as independent units of action, or as "a nearer cause of gene mutations."

As mentioned in Section 4, energy transfers are not always independent units of action when they occur too close to each other. This might happen because the effect of one energy transfer excludes, or makes useless, an analogous effect of other energy transfers, as in the saturation effect, or, on the contrary, because cooperative action of two adjacent energy transfers is helpful to produce an effect. A still different interaction due to quantum mechanical interference phenomena may occur when more than one energy transfer takes place within a single molecule.

Consider now the phenomena associated with an energy transfer. On the average, approximately one out of three energy transfers produces an ionization, i.e. ejects an electron from its place; the other energy transfers produce simple excitations. An excess positive charge is temporarily left in the atom or molecule (positive ion) from which an electron has been removed. The ejected (tertiary) electron undergoes a series of processes analogous to the energy transfers. These processes often occur very close to each other because of the small energy of the tertiaries. When the energy of an electron is so small that it cannot excite any more atoms, the electron keeps on wandering and undergoing large deflections until it is captured somewhere with release of excitation energy; most frequently it is captured by a neutral atom with formation of a negative ion. Positive and negative ions tend finally to neutralize their charges with further release of energy. A large fraction of the tertiary electrons have not sufficient energy to produce any ionization; very few of them produce very many ionizations. On the average, two ionizations arise, directly or indirectly, from every tertiary electron. Thus the ionizations produced by tertiaries bear to those produced directly by secondaries the same ratio (2:1) as the energy transfers without ionization bear to those with ionization; hence the total number of ionizations is just about equal to the number of energy transfers of secondary electrons.

No method is available to vary the spatial distribution of the ionizations and excitations accompanying an energy transfer, because, as stated above, the quality of the energy transfers does not depend appreciably on the quality of radiation. Therefore it is impossible at present to analyze the "cause" of the production of gene mutations beyond the stage of the physical action represented by the energy transfers of the secondary electrons. *Therefore it is also impossible to recognize single ionizations as independent units of action:* Some previous interpretations have been inexact on this subject, inasmuch as it was not considered that a change in the wave-length of X-rays does not affect the distributions of ionizations along the side-tracks of tertiary electrons, but only the distribution of energy transfers of secondary electrons. Also, in the previous sections of this paper "energy transfers" should always be considered instead of ionizations.

Jordan (1938b) and Lea (1940) recognized the impossibility of analyzing the action of the energy transfers and considered the production of a tertiary electron together with its whole action as the fundamental unit of action, the "ion cluster." An ion cluster contains on the average three ionizations (see above) but this average value is not the most frequent one (single ionizations are most frequent). Considering ion clusters as the fundamental units means neglecting all those energy transfers which lead to simple excitations.

A few more remarks can be made concerning the biological importance of ionization phenomena. On the one hand, the separation of charges which takes place at ionization gives rise to a metastable storage of activation energy which is released only at recombination; the longer this energy is available, the more likely it is that it can be used for any specific purpose, as, for example, for a biochemical change. Moreover, the separated charges might conceivably affect electrostatically

the physico-chemical phenomena involved in biological systems. On the other hand, however, the amount of ionization produced by radiation is an important quantity mainly because it is directly measurable, at least in gases, and because it represents a fair index of the amount of energy absorbed by matter and of the number of energy transfers of fast secondary electrons. The single ionizations themselves should not be considered as the units of biophysical action on the basis of the present knowledge, as shown above. Biochemical reactions may be activated by radiation independently of any ionization, that is, by simple excitations.

The distribution in space of negative ions is the result of a long process of diffusion of very slow electrons and has little bearing on biological actions. Therefore it is important to distinguish between the distributions of ions of different sign. Cloud chamber pictures may give a misleading picture of the spatial distribution of radiation effects, inasmuch as they do not show this distinction. Finally the difference between the distributions of positive and negative ions has been disregarded in theoretical calculations of the ion recombination, which were directed to determine the radius of action of α-particles (Jaffe, 1914; see also Jordan, 1938a). Therefore values too large have been obtained for this quantity.

SUMMARY

The interpretation of radiogenetic experiments, which is given by the hit theory, may be subjected to criticism. The random distribution in space of the physical action of radiation seems to be only one among the factors determining the frequency of mutations. The lack of influence of the wavelength of X-rays on their genetic effects can be discussed and understood independently of the hit theory. A generalized treatment of the dependence of the effectiveness of radiation on the ion density enables us to consider the influence of several hitherto neglected factors on the theoretical relationship calculated by Lea (1940). A modified pattern of biophysical analysis of the X-ray action is suggested, showing that the procedure usually intended to determine the "nature of the hit" is equivalent to an investigation of the "nearest cause" of a radiobiological action.

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NEW BIOLOGICAL BOOKS

The aim of this department is to give the reader brief indications of the character, the content, and the value of new books in the various fields of Biology. In addition there will frequently appear one longer critical review of a book of special significance. Authors and publishers of biological books should bear in mind that THE QUARTERLY REVIEW OF BIOLOGY *can notice in this department only such books as come to the office of the editor. The absence of a book, therefore, from the following and subsequent lists only means that we have not received it. All material for notice in this department should be addressed to B. H. Willier, Editor of* THE QUARTERLY REVIEW OF BIOLOGY, *Department of Biology, Homewood Campus, The Johns Hopkins University, Baltimore, Maryland, U. S. A.*

INCREASE AND MULTIPLY

Being a review of *Nation and Family* by Alva Myrdal, New York (Harper and Brothers), 1941. Pp. xv + 441. 9½ x 6 inches. $4.00. *By Antonio Ciocco, U. S. Public Health Service.*

Man, long ago, made the interesting discovery that there are means whereby the mating urge could be satisfied while the chances of reproduction are materially reduced. This discovery has been one of the main elements to upset the best laid plans of social reformers who seek to regulate the sexual activities of the individual. The tremendous technological progress of the last century and the great increase in scientific knowledge have extended also to the field of contraception and birth-prevention, and as a consequence those who guide the destinies of the societal group as well as its morals are faced with an increasingly baffling problem. Their difficulties are enhanced at present because contemporary students of population have reversed the viewpoint of the preceding generation and clamor about the dangers of depopulation. During the past two decades in Belgium, France, Germany and Italy, legislative measures to stimulate child-bearing have been introduced. Sweden has followed suit and between 1934 and 1938 a Population Commission within the Swedish legislative body was organized to study the "population problem." In this book Myrdal summarizes the work of the Commission and comments on the results achieved, the recommendations made, and laws passed.

Sweden has a population of only about 6½ millions and it is predominantly a non-industrial country, yet it has always claimed the interest of demographers and other social scientists. The reasons are rather obvious. First, the present system of vital statistics registration dates back a long time and is one of the most reliable of any country. Second, the Swedes have experimented with many social reforms on a national scale without abandoning any of the overt characteristics of a democratic form of government. This has led many to see in Sweden the paragon of our civilization and to advocate imitation of its mores and laws. Even if this were possible, there are many features of the demographic trends in Sweden that deserve careful consideration. They are clearly outlined in the first part of the book, in the excellent description of the population characteristics of the country. The population has been increasing very slowly; the death rate has declined to a level below which it cannot go; the marriage rate is low; and the illegitimate birthrate is high. Thus, as many students of population prophesied, the trends of mating behavior seem to lead to a breakdown of the family as at present constituted. The author fears it and so apparently have the Solons of Sweden.

To forestall the danger, the Swedish Population Commission suggested a number of measures certain of which have been enacted into laws. The measures proposed and instituted, described in the second part of the book, not only serve to relieve from all of the classes of the population some of the economic burdens which accompany the formation and maintenance of a household, but go much further in the direction of repealing what are still considered, in this country at least, fundamental principles of morality. Anti-contraceptive laws are abolished, and sex education is regarded as an item of the scholastic curriculum. Laws regarding sterilization and the induction of abortions have been broadened but to what extent is not clear from the author's exegesis. As Myrdal points out the enactment of these laws constitute a victory for the neo-Malthusian movement. They certainly represent a frank recognition of the sex problems but in what manner they will stimulate the production of babies is not easily understood. However, there are other measures that bear directly on the matter of encouraging childbearing. Within the framework of sickness insurance and free medical care—measures which place Sweden in the vanguard relative to State medicine—the government furnishes loans to married couples preparing to set up a household; gives a "maternity bonus" to all mothers, except those in the

high income brackets; provides for free school lunches for children; provides for equality of treatment of married and unmarried mothers, legitimate and illegitimate children. How successfully will these measures achieve their purpose? The author is hopeful but also points out that the laws still assume that the woman is to be fundamentally a home-maker, a function which she shows little desire to exercise so long as she has economic opportunities equal to those of the male. It is likely that the author has perceived and indicated the crux of the contemporary problem. If this is so, one can expect that the Swedish experiment will give results similar to those achieved in other countries and in other periods. The failures of the past derive not from lack of sizeable efforts but from the naïvité of the reformers who see the "problem of population" now as a problem of economics alone, now as one of moral behavior only and so on, but never in its entirety, as a problem of human biology. Although the author does take a broader view than usual of the problem, one notes unnecessary emphasis on the (a) need for and value of positive action, (b) goodness of the measures adopted in Sweden, and (c) distinction between the Swedish laws and those of other countries. Nevertheless, it can be said that this work constitutes one of the most interesting surveys of the population problem within the past decade, and one which will undoubtedly influence greatly American thought on the subject.

BRIEF NOTICES

EVOLUTION

PROBOSCIDEA. *A Monograph of the Discovery, Evolution, Migration and Extinction of the Mastodonts and Elephants of the World. Volume II. Stegodontoidea, Elephantoidea.*

By Henry Fairfield Osborn. Edited by Mabel Rice Percy. The American Museum Press, New York. $20.00. 12½ x 10¾; 805–1675 + 30 plates + 2 folding charts; 1942.

Somebody once told a story of an international competition for the best book on elephants. It supposedly produced manuscripts by an Englishman on "Where and how to shoot elephants," by a Frenchman on "L'elephant et ses amours," by a German for a "Handbuch des anatomischen Aufbaus und der geographischen Verbreitung der vorgeschichtlichen Elefanten und ihrer jetztzeitlichen Verwandten, mit einem Anhang über die Entwickelungsgeschichte des Zahnsystemes," and by an American, who won the prize, on "The American Imperial Elephant, the biggest of them all." To some laymen it may also be merely amusing to hear that someone has actually written nearly 2500 large printed pages on the history of a group of mammals of which our recent elephants are the last survivals. If, however, they will examine this monumental and admirably illustrated work, they will find that this is the best documented, most nearly complete and, hence, the most convincing account of the entire evolution of one animal group that it has ever been possible to assemble. This scholarly history of the order of proboscideans by America's foremost palaeontologist, the late Professor Osborn, covers a period of some 60,000,000 years, spreads over four continents and reveals nature's constantly changing and widely diverging experiments in producing the largest of all terrestrial mammals.

The first volume of this monograph appeared in 1936 (reviewed in this Journal, vol. 12, p. 211), the year after its author's death. The present, second volume has been very ably edited by Osborn's former secretary, Miss Mable Percy. There has been added a chapter on the geologic succession of the proboscideans by one of Osborn's former assistants, E. Colbert, and a brief appendix on proboscidean dental histology by G. G. Simpson. The second volume deals with the last two of the five proboscidean suborders or superfamilies, the Stegodontoidea and the Elephantoidea and contains the general summary regarding the affinities, migrations, and phylogeny of the entire order. Here are also given a supplementary bibliography and the general index for both volumes.

The enormous amount and varieties of fossil remains which form the basis for the large descriptive parts of this work have been unearthed over a period of more than three hundred years. In this material Osborn distinguished 5 superfamilies, 8 families, 21 subfamilies, 44 genera, and 352 valid species and subspecies. No wonder the pedigree of the Proboscidea is a vastly complex affair; and still there remain undoubtedly many gaps in our knowledge of ancestral elephants to be filled by future discoveries! The construction of this pedigree is based to a large extent upon the careful analysis of the remarkable and manifold specializations in the dentition. It has been possible to show that all the many forms of molars are derived from simple four-coned ancestral grinding teeth. Numerous evolutionary trends, accounting for the varied changes in the skeleton are demonstrated step by step with a wealth of technical detail which itself had facilitated the conscientious reconstructions of the outer forms of the amazing array of extinct proboscideans.

Osborn has been equally interested in the evolution of man as in that of the elephant. Comparisons between these two great histories often occupied his mind, as is indicated by the following paragraph from his own pen, quoted in the summary of the volume under review:

An insatiable *Wanderlust* has always possessed the souls of elephants as it has those of the tribes and races

of man. Not only to overcome the changes and chances of this mortal life, but also to gratify their intelligent curiosity ever to explore afresh forests, pastures, fields, rivers, and streams, they have gone to the very ends of the earth and have far surpassed man in adapting their clothing and teeth to all possible conditions of life. Thus the romances of elephant migration and conquest are second only to the romances of human migration and conquest. Variety is the spice of elephant life, as it is of human life, and the very longing for a change of scene and of diet has been the indirect cause of what in scientific parlance we term *adaptive radiation*—the reaching out in every direction for every kind of habitat, in itself the *cause* of radiating or divergent evolution and adaptation. It is to this predisposition to local, continental or insular, and world-wide wanderings that we attribute the many branches and sub-branches which have been developed in this remarkable family.

A Middle Eocene Flora from the Central Sierra Nevada. *Contributions to Paleontology, Carnegie Institution of Washington Publication 534.*

By Harry D. MacGinitie. Carnegie Institution of Washington, Washington, D. C. $2.50 (cloth); $2.00 (paper). 11¼ x 8⅝; iii + 178 + 47 plates; 1941.

It was the search for gold back in the era of the "forty-niners" that the outcrop of plant-bearing sediments were first uncovered in the Sierras. MacGinitie gives a brief account of the development of gold mining from placer methods to hydraulic mining, and the manner in which the beds became known.

> The miners became, indirectly, fossil collectors, since they piled the silicified logs . . . which occur in abundance, in windrows along the edges of the sluicing channels in order to facilitate the movement of the finer gravel. They also noted the fossil leaf impressions in the clay beds. These were brought to the attention of the United States geologists under J. D. Whitney about 1875. A good collection was made at Chalk Bluffs and sent to Leo Lesquereux for determination. . . . Lesquereux . . . published the results of his study as a *Report on the fossil plants of the Auriferous Gravel deposits of the Sierra Nevada.* This report is one of the classic papers in the literature of paleobotany.

The present work is concerned with the fossil plants of Chalk Bluffs, a region 50–60 miles northeast of Sacramento, with an elevation varying from 1000 to 3000 feet. The various localities from which the Chalk Bluffs flora came are all considered to fall in the same stratigraphic horizon, with the possible exception of that at Cherokee. Fossil collections were first made about 1870 but the localities were temporarily lost after the decline of gold mining in the region. It was not until 1931 that members of the U. S. Forest Service rediscovered the rich fossil deposits.

MacGinitie began his survey in 1933. In the present paper he gives interesting discussions of the geology of the region, climate and vegetation, composition of the flora and relationships of the fossil species, and environment of the fossil flora (including geographical distribution of similar living species, abundance of fossil species, ecological and climatic conditions, distribution and related problems). He finds that "The Chalk Bluffs flora is shown by its composition and state of evolution to be the oldest of the six well known older Tertiary floras of the Pacific slope." The forms represented (over 75 are described) indicate a humid, subtropical climate for this region in early geologic times. Existing representations of these forms inhabit two areas: Southeastern North America including Mexico and Central America, and Southeastern Asia. Of the fossil angiosperm species, 36, or 54 per cent, are trees; 24, or 36 per cent, are shrubs or small trees; and 7, or 10 per cent, are vines.

The excellent illustrations show characteristic views of the Chalk Bluffs region, modern forest vegetation of California and Mexico (9 plates), and fossil types (38 plates). A useful bibliography of four pages is included and an index of genera and species.

How Man Became a Giant.

By M. Ilin and E. Segal. Translated by Beatrice Kinkead. Illustrated by A. Komarov and E. A. Furman. J. B. Lippincott, Philadelphia. $2.00. 8 x 5⅜; 270; 1942.

"There's a giant in the world. He has hands that can lift a locomotive without the least effort. He has feet that can travel thousands of miles in a single day. He has wings that can carry him up above the clouds, higher than a bird can fly. . . . He has eyes that can see the invisible . . . This giant is man." In this fashion the meaning of the title is explained in the introduction of this book for adolescents on man's rise above his animal ancestry.

This is a vivid popular account of human evolution with the main emphasis on the development of man's ability to fashion tools, to build homes, to formulate language and social organization, etc. In general, the authors have been guided closely by the best scientific evidence, so far available, but at times they draw rather heavily upon their imagination, particularly in those parts of the story regarding which the scholar would still have to admit large gaps in his knowledge.

Among the many recent attempts to reconstruct man's remote history for the layman, this little volume recommends itself by notable originality, good style and very attractive illustrations. Throughout, the one theme is developed enthusiastically and convincingly: Man was once the slave of nature, as are all his fellow creatures, but he freed himself and became the master of the world. It is not even mentioned, however, that man has progressed pitifully little toward mastering his own nature.

GENETICS

THE GENETIC AND ENDOCRINIC BASIS FOR DIFFERENCES IN FORM AND BEHAVIOR *as Elucidated by Studies of Contrasted Pure-Line Dog Breeds and Their Hybrids. American Anatomical Memoirs, Number 19.*

By Charles R. Stockard and Collaborators with Special Contributions on Behavior by O. D. Anderson and W. T. James. The Wistar Institute of Anatomy and Biology, Philadelphia. $7.50. 10 x 6¾; xx + 775 + 113 plates; 1941.

The demonstration that, in human beings, extreme diversities in type and constitution are associated with various modifications and diseases of the endocrine glands has led a number of investigators to suggest the possibility that hereditary modifications of the glands of internal secretion may account for the establishment of racial differences in man. It can be imagined that some relatively simple change in the genetic constitution which would bring about over-activity or under-activity of one or another of the endocrine glands might result in the establishment of a type which would be very distinctive both in its form and behavior. In such a case, the endocrine complex would become an important intermediary mechanism in evolution. The attempts of the late Doctor Stockard to test this thesis by exhaustive investigations of the morphological and behavioral characteristics of various pure breeds of dogs and their hybrids mark a milestone in the development of the study of endocrinology.

The data presented in the present monograph give in detail the results of the work at the Cornell Anatomy Farm since 1926. It is indeed fortunate that the greater part of the manuscript had been completed by Stockard before his death in 1938 but it is a matter of great regret that certain sections, notably the final integration of the results concerning the relation of the endocrines to type, are lacking. Without such an integration the various sections of the book stand as more or less isolated contributions, and to arrive at a general picture of the results of the work as a whole is somewhat difficult. It is clear that despite the great mass of material which has been obtained and the critical care with which it has been weighed and presented, many phases of the work are still in preliminary stages. Knowledge of the genetics of the various breeds of dogs is still relatively limited and the constant association of particular histological characteristics of the endocrine glands with particular physical types of dogs is by no means proved. These difficulties were clearly recognized by Stockard, however, and the data are presented with the reservations which these limitations demand. This is a pioneering investigation carried out with patience, insight and care, and its results are of great significance not only in relation to the immediate problem at hand but also to many other lines of work.

GENERAL BIOLOGY

BIOLOGICAL SYMPOSIA. *Volume IV. I. Population Problems in Protozoa. II. Experimental Control of Development and Differentiation. III. Theoretical and Practical Aspects of Polyploidy in Crop Plants. IV. The Species Problem.*

Edited by Jaques Cattell. Foreword by Sewell Wright. The Jaques Cattell Press, Lancaster, Pennsylvania. $2.50. 9⅛ x 6¾; xi + 293; 1941.

This book includes four symposia on such diverse subjects as Population problems in Protozoa, Theoretical and practical aspects of polyploidy in crop plants, Experimental control of development and differentiation, and The species concept.

The first symposium is concerned primarily, though not exclusively, with laboratory populations. Effects of both the composition of the environment and of interactions between organisms are considered. There is first a brief historical introduction followed by papers on the ecological aspects of natural populations, on laboratory populations of flagellates, of ciliates, of blood-dwelling forms, and finally a paper inter-relating the work on protozoan populations to work on populations of animals in general. Particular emphasis is laid on the effect of the density of the original population on growth.

The second symposium deals with several aspects of polyploidy. The practical aspects of the subject are dealt with in papers giving the results of induced polyploidy in floriculture and in breeding of crop plants. The method seems to be of value both in the immediate production of new varieties and in the transference of genes from one variety or species to another. The use of polyploidy in investigating more theoretical matters is shown in two other papers; one giving the results of investigations on evolution in the genus *Nicotiana*, the other discussing the occurrence and distribution of mutations in polyploids.

In the third symposium, four papers are given on particularly well analyzed developmental systems. The first discusses the systems of reactions leading to eye pigmentation in *Drosophila* with emphasis on the rôle of individual genes. The second considers the effects of induced polyploidy on development in plants, particularly *Datura*. The third treats the developmental reactions leading to the production of feather color patterns in the domestic fowl. Particular emphasis is laid on studies of the interaction of melanophores and feather germs of different breeds. The final paper deals with investigations of the rôle of hormones in plant development.

The last symposium is concerned with an analysis of the species concept and with some of the factors involved in species formation. The first paper is primarily a discussion of the species as viewed by the museum taxonomist. The method of action of natural selection

is considered in the second paper with emphasis placed on selection of physiological characters with incidental selection of correlated morphological characters. The third paper discusses geographical varieties in certain plants with an evaluation of the rôle of heredity and environment in determining the characteristics of the individual plant. The last paper is a consideration of the rôle of isolation on speciation in the insects of the Hawaiian islands. The symposium emphasizes the information on evolution that may be derived from morphological and taxonomic studies in the field.

In general this series of symposia is an excellent addition to the previous ones. The value of most of the papers is enhanced by short lists of references, though in a few cases such lists are regrettably lacking.

GENERAL BIOLOGY FOR COLLEGES.

By Gairdner B. Moment. D. Appleton-Century Company, New York and London. $4.00. 8¼ x 5¾; xix + 661; 1942.

The author has written this text with three principle aims in view: to present the material in as clear and logical a way as possible; to give the evidence for the conclusions that are made; and to show the human significance of the subject. These aims are excellent and in many respects the book lives up to them. It devotes considerable space to the experimental evidence, giving space to newer work as well as to the older, classic cases. The historical development of many of the subjects is worked in as an integral part of the text. The functional aspect of biology is emphasized, though morphology is not neglected. An extensive glossary and numerous excellent illustrations add greatly to the clarity of the text.

In many respects then this is an excellent book so that it is to be regretted that it does not always live up to the author's aim of clear presentation. Particularly in the early chapters, concepts and terms are introduced for which the student has not been adequately prepared, and the explanations of these are often far too brief. In several places examples are introduced to make a certain point clear. However, these examples are often ones which would be familiar only to the trained biologist. Not infrequently the present reviewer had the impression that the author was writing with his professional colleagues in mind rather than the student. If somewhat less material were introduced and more fully explained, the reviewer believes that the student would be less likely to be left floundering in a maze of unfamiliar ideas.

The general plan of the book is good. It starts with discussions of the science of biology in general and the universal characteristics of living things. Several chapters are then devoted to plants, including structure, physiology, and reproduction. Following this, ecological relationships of plants and animals are considered. Then come a number of chapters on animal morphology and physiology including nervous and hormonal coordination. The more general biological problems of reproduction, development, heredity, and evolution are then discussed. The last two chapters are a history of life on the earth and a fairly detailed review of the phyla of the animal kingdom. Lists of "Useful References" are given at the end of each chapter and there is an extensive index.

BRITISH GRAHAM LAND EXPEDITION 1934–37 SCIENTIFIC REPORTS. *Volume I, No. 8, Tidal Observations in Graham Land. Part I, by Brian Roberts; Part II, by R. H. Corkan: No. 9, A Bibliography of Antarctic Ornithology, by Brian Roberts.* Also *Contents* and *Introduction; British Graham Land Expedition, 1934–37, Scientific Reports, Volume I, Nos. 1–9.*

The British Museum (Natural History), London. No. 8: 1s., No. 9: 2s. 6d. 12¼ x 9; No. 8: 327–335, No. 9: 337–367; Contents and Introduction: 6; 1941 (paper).

These two numbers conclude Volume I of this important survey (cf. Q. R. B., Vol. 16, p. 489 for nos. 1–6). Number 7 describes the two automatic gages used in making tidal observations and discusses the reduction of the tidal observations of the present expedition to Graham Land and of the expedition in 1920–22. Information is also given on tidal data of Drake Strait. Tables and text figures and a map form part of the report.

Concerning the bibliography of antarctic ornithology Roberts says:

> It is still too early to make the publication of such a work profitable. With the present taxonomic confusion, even the compilation of a list of species recorded from this interesting region presents serious difficulties. No adequate series of antarctic or sub-antarctic specimens, representing forms from the entire breeding range of a single genus, have yet been brought together; and if all existing collections were to be combined, they would still be quite inadequate for the purpose. Recent studies have revealed intricate diversity among certain groups, while others appear to have an extremely wide distribution without exhibiting any marked geographical variation. A sound classification of antarctic birds must await the collection of very many more specimens.

For the above reasons Roberts confines himself to providing necessary material for future work. He gives (1) a list of antarctic expeditions, with observers and collaborators who have published ornithological results (this aims to include the ornithological results of every antarctic expedition up to 1940); (2) publications listed in (1); (3) miscellaneous publications based on

museum and literary research; and (4) an index of localities.

For those who have the previous numbers of this fine survey—probably the last of its type for many years to come—a table of contents and introduction are provided.

A Symposium on Hydrobiology.

By Various Authors. The University of Wisconsin Press, Madison. $3.50. 9¼ x 6; ix + 405; 1941.

It is truly fitting that one of the recent very important contributions to the science of hydrobiology should come, in the form of the present *Symposium*, from the University which has done so much to advance that science in our country.

The scope of hydrobiology has, in the past few years, become so great that investigators in the field have been forced to make extensive use of chemistry, geology, and physics in order to solve their many problems. The present *Symposium* emphasizes very well this trend. The various papers deal with sedimentation, the rôle of dissolved gasses and of treated and non-treated sewage on various aquatic organisms, methods of chemical treatment of natural and artificial bodies of water, the rôle of sky and solar radiation in the determination of lake populations, and the relation of hydrobiological studies to problems of hygiene and sanitation. The volume brings out the breadth of the field which is included under the term hydrobiology and shows how important economically such studies are. Abstracts of papers presented in a volunteer program are included.

The *Symposium* is well edited and the papers are carefully written and adequately illustrated. It is impossible to pick out any one paper which is worthy of special note since each covers its topic adequately and, most important, each presents several unsolved problems in such a manner as to stimulate further investigation. It is unfortunate that no index has been provided.

Book of Bays.

By William Beebe. Harcourt, Brace and Company, New York. $3.50. 8½ x 5½; xviii + 302; 1942.

A popular account of the second voyage of the yacht *Zaca* which carries us on a leisurely journey along the 3000 miles of the Pacific Coast from Lower California to the shores of Colombia. Beebe's ability to infect the reader with something of his own never-ending curiosity and boundless enthusiasm concerning the lives of animals of all kinds, including the human animal, is well exemplified in this book, and his brief pictures of such diverse subjects as the homing instincts of limpets, the iridescent colors of the boa constrictor and the joys of circus day in Salvador, make entertaining reading indeed. The critical zoologist must take exception to some of the broad generalizations contained in the introductory chapters on the evolution of aquatic animals and to the misuse of some technical terms, such as the reference to the existence of "gills" in the human embryo and the use of the term "cetaceans" to designate the sea-lions. The layman, however, will leave the book with an increased knowledge of some of the problems with which the biologist is concerned and an added interest in natural history.

The Open Book of Wild Life. *An Introduction to Nature Study.*

By Richard Morse. With a Foreword by David Seth-Smith. The Macmillan Company, London and New York. $3.00. 8¼ x 5⅝; viii + 240 + 16 plates; 1941.

Natural history and evolution are the keystones around which this treatise on British fauna and flora is built. The work is intended primarily for popular consumption, and as such presents the human interest side of biology in a very logical manner and in non-technical terms. Particular emphasis has been placed upon the social life among the lower forms, and the means whereby they meet the hazards of their natural environment and hence insure their own individual survival as well as the survival of the race.

The work is illustrated with a number of excellent line drawings and photographs (some in color), and is carefully indexed. In the hands of British nature lovers, the volume should prove to be a worthwhile contribution.

A Naturalist in Canada.

By Dan McCowan. The Macmillan Company, Toronto. 15s. 8½ x 5½; xii + 284; 1941.

This book consists of a series of disconnected essays on various matters that come to the attention of the field naturalist. Not only do the habits and appearance of plants and animals figure in it, but also such related subjects as geology, folk-lore, the age in which animals live, the melting of the glaciers, forest fires, etc. The book is not only good natural history, but also good literature. It is illustrated with numerous photographs by the author, and two humorous drawings contribute not a little to the reader's enjoyment.

University of Washington Publications in Biology. *Volume 10, Nos. 1, 2, 3. The Coleoptera of Washington. Carabidae: Agonini,* by Barbara Gray

and Melville H. Hatch; *Sphaeritidae and Histeridae*, by Rita Margaret McGrath and Melville H. Hatch; *Buprestidae*, by Frank M. Beer and Melville H. Hatch.

University of Washington Press, Seattle. $1.50. x 7; 144; 1941 (paper).

HUMAN BIOLOGY

SEA OF CORTEZ. *A Leisurely Journal of Travel and Research with a Scientific Appendix Comprising Materials for a Source Book on the Marine Animals of the Panamic Faunal Province.*

By John Steinbeck and Edward J. Ricketts. The Viking Press, New York. $5.00. 9¼ x 6; x + 598 + 40 plates + 2 charts; 1941.

FORGOTTEN WATERS. *Adventure in the Gulf of California.*

By Randolph Leigh. J. B. Lippincott Company, Philadelphia. $3.00. 9 x 6; 324 + 24 plates + 2 maps; 1941.

After an unmerited neglect of about two centuries, one of the world's romantic bodies of water is being discovered anew. The "Vermilion Sea" (so-called on account of the great quantity of plankton in its upper reaches) differs in many ways from most other bodies of water. It is one of the very few gulfs without a bar at the entrance, but notwithstanding this it has a well marked *seiche*, the greatest tide-fall in the Pacific, and one of the greatest tidal bores in the world. It has one of the richest and most diversified marine faunas known (the town of El Mulegé would be an ideal site for a laboratory of marine biology) and at Cape San Lucas the boundary between the Californian and Panamic provinces is almost as sharply discontinuous as Wallace's Line in the East Indies. Nowhere else in the world except possibly at Bermuda, is the influence of the tropics felt so far north. The pearl industry of La Paz is second only to that of Manila, and cannibalism continued on Tiburon after Thackambau had suppressed this practice in Fiji.

To those who are imbued with the spirit of Kipling's poem about the explorer whom an inner voice impelled to search for something lost behind the ranges, the Gulf holds up a beckoning finger and a "come-hither look in the eye." Nowhere is the sea water more transparent than off the coast of Cochore, nowhere are the sunsets more brilliant than at Bocochibampo, and nowhere are the stars so bright or so numerous as in the sky of the Sonoran desert, fifty odd miles from the nearest water hole.

The recorded history of the gulf begins with the rivalry between Cortés and Mendoza, both of whom sent expeditions to its head waters to look for the Strait of Anian, a mythical channel thought to communicate with Puget Sound, thus making California the world's largest island. Although neither one found the strait, neither one could convince the European cartographers of its non-existence, and it continued to appear on subsequent maps until 1701 when Padre Eusebio Kino, the missionary who made history as a by-product, completed his journey by land from Pimería Alta (Arizona) around the end of the gulf, demonstrating conclusively the peninsularity of Baja California.

Steinbeck's story of the expedition which he and Ricketts led into the gulf in search of biological material reads like one of his novels. The narrative of adventure holds the attention of the reader by his descriptions of the small boys who swarmed over their boat at every port, trying to earn a few centavos by bringing specimens, the officials who stared at their impressive looking documents without quite understanding them, the shiftless Seri Indians completely deficient in that ferocity that characterized their ancestors, as well as by his vigorous account of the climatic vicissitudes through which they passed. But Steinbeck never forgot that the expedition was primarily for scientific purposes, and he did his share of turning rocks and gathering mollusks, worms, and echinoderms, incidentally lacerating his hands on the barnacles and toughening his epidermis in the salt water.

Ricketts is also an author of standing. He has contributed to this work a chapter of instructions to collectors, very helpful lists of species taken, and bibliographic references. No similar survey of this region has been undertaken since Johann Xantus stored his collections in Manzanillo and slipped through the blockading fleet of the French in a rowboat at night, to be picked up by a passenger boat on the open ocean the next day. It does not take much imagination to visualize the shade of this biological pioneer following the cruise of the *Western Flyer* with interest and sympathy.

The object of Leigh's expedition was to study the silt deposition of the Colorado. His conclusion is that in times past this was adequate to compensate for the erosion of the delta by the tidal bore, but that Boulder Dam has destroyed this balance, so that drastic steps must be taken to prevent the waters of the gulf from eventually submerging the Imperial Valley. This theory is not likely to meet with universal acceptance. In the past forty years no silt from above Boulder Dam has reached the delta, owing to the desilting dams at Parker and Laguna. Further, the peak load of silt that a stream can carry is a unique function of its velocity and flow volume, and normally these are such that the saturation of the water desilted at Laguna is restored above the delta. While Lake Meade was filling the flow volume was naturally reduced, and the head waters of the gulf doubtless did advance northward somewhat, but when Lake Meade had filled, the flow volume was restored. As the quantity of water removed for agricultural purposes is increased the flow volume will be diminished accordingly, but a perceptible reduction of siltation from this cause is probably a long way in the future.

But Leigh does not confine his book to his problem. He writes delightfully of the seven towns on the gulf shore, which he identifies with the Seven Cities of Cibola. His narrative of the voyages of Alarcón, Link, Consag, and the other pathfinders of early American history strikes fire from the imagination, though he is guilty of a *lapsus calami* in stating that Nuñez and Estebanfco were killed by Indians at Culiacán. As a matter of fact, Estebanfco met his death in Arizona while serving as guide for Marcos de Niza, while Nuñez returned to Spain and many years later explored the upper reaches of the Rio de la Plata.

There are a few other slips—such as the estimated tidal difference of 50 feet near Phillips' point, the inclusion of the seals among the Cetacea, and the statement that Guaymas is likely to supplant Hermosillo as metropolis of Sonora, when probably the reverse was intended. But these do not detract from the enjoyment that the reader will derive from the perusal of the book.

To those who enjoy travelling in unfrequented and unfamiliar places, but whom circumstances compel to remain close to their hearthstones, these books weave a magic carpet on which we may penetrate in imagination beyond one of the few remaining frontiers in North America—a frontier incidentally not far beyond our own borders. To all such a great treat is held in trust between the covers of these books.

PRINCIPLES OF ANTHROPOLOGY.

By Eliot Dismore Chapple and Carleton Stevens Coon. Henry Holt and Company, New York. $3.75. 9¼ x 6⅛; xi + 718; 1942.

Anthropology as a science is scarcely one century old. In this country the term anthropology is applied to what in Europe is mostly called ethnology. For a long time this science concerned itself merely with the curious habits and queer handcraft of "primitive people." In the last few decades, however, the chief interest shifted to, and rapid advances have been made in, the analysis and understanding of man's behavior and social relations, including those of modern "civilized" races. In its most recent development, anthropology has come to be defined as the science of human relations. Individuals are grouped in familiar, occupational. and institutional groups through relations which are determined by our habits, by techniques, by adaptation to environment, and by symbols and conventions for transmitting information, all of which together form our culture. These relations change with time and have become steadily more complex.

Guided by the latest views of modern anthropology the authors of this scholarly work have succeeded in supplying a much needed, up-to-date and comprehensive textbook of "human relations", of great service to students as well as teachers. The book will also be very stimulating to historians and instructive for biologists, interested in behavior. The authors have wisely limited their attention to facts directly ascertainable from observations and have selected and arranged their objective descriptions in a clear and orderly manner, leading to amply supported and often novel deductions.

The wide scope of the book is best indicated by naming some of the most significant titles in the table of contents: The comparatively brief first part attempts to explain at least some of the biological foundations of human relations, especially the physiology of emotions, the development of conditioning and of personality, etc. This rather ambitious introductory section contains a few claims with which not all neurologists and psychologists will agree. A second part of over 200 pages discusses environment and technology, in particular such topics as manufacturing, gathering, husbandry, transportation, and division of labor. A third part, of 188 pages, is devoted to the systematic description of the development of institutions, such as the many and often complicated aspects of the family, and the fascinating and at times disillusioning history of political, economic, and religious institutions. The last two parts, of 231 pages, consider symbols and human relations, discussing such varied matters as rites of passage, rituals, magic, language, art, games, warfare, money, and law. The last paragraph of the conclusions is especially timely and worth quoting here:

> Because anthropology, as we have seen, regards man as a whole, it can provide a unifying center around which a science of human relations can grow. The technological problems which plagued the people of an earlier day, problems of food and shelter and health, of more efficient means of transportation and communication, have largely been solved. We can look forward to increasing technical triumphs provided we are able to master the maladjustments in human relations resulting from technological change. At the present time, little attempt is made even to use what we already know in dealing with such problems. Only when the science of human relations becomes as fully developed as the older natural sciences can we hope to eliminate sources of individual maladjustment, bring about harmonious relations between the many groups making up a single nation, work out more effective and democratic systems of government, and extend their sway to the relationships between nations. Only with such a science can the basic problem of our civilization be solved,—how to increase our human adjustment and at the same time to increase our technological efficiency.

The appendix contains an excellent reading list of 70 titles, a useful glossary, needed in view of the specialized definitions of many words not in common use, and a detailed index.

THE SOCIAL LIFE OF A MODERN COMMUNITY. *Yankee City Series. Volume One.*

By W. Lloyd Warner and Paul S. Lunt. Yale University Press, New Haven; Oxford University Press, London. $4.00. 9¼ x 6; xx + 460; 1941.

"Yankee City," the research site, is an old New England town, chosen for study because it is a well integrated community "where the various parts of society were functioning with comparative ease," it has a few industries and factories, is autonomous and not a satellite of a large city, contains a number of ethnic groups and has a population of between 10,000 and 20,000 (actually 17,000). The information for this volume and the five others contemplated in the series, was assembled by an elaborate system of interviewing, observing, study of newspaper items and genealogies, etc., over a period of 10 years.

A social hierarchy in this community was discovered to consist of six classes, with only 3 per cent of the population falling into the two upper, and 85 per cent being fairly evenly distributed into the three lowest. The upper-lower was the largest of all classes, the lower-lower the smallest of the three lowest. The sharp breaks in numerical and percentual size of the classes occurring at the junctures upper-middle-lower-upper and lower-middle-upper-middle are construed to indicate that "the movement into and out of the upper-middle class is relatively less than in the other classes." The upper-upper class had a higher than average proportion of men, with the other classes presenting a fairly even distribution with regard to sex ratios. Residence (location and kind), marital condition, number of children, property ownership, budget items, occupation, membership in clubs, lodges, fraternities and churches, education of parents and children, crime and delinquency, reading habits (kind and number of books, magazines and newspapers bought or read) and the use of the public library, movie attendance, the choice of doctor, lawyer and other professional services, and proportion of ethnic members, all appear to be influences in some way by class factors—not necessarily monetary.

The first half of the book is given over to a description of the method, a description of the town and its biological characteristics, and a series of "profiles" presenting composite pictures of members of the various classes and illustrating as well mobile processes, both up and down the social scale. The later chapters give statistical analyses of the class similarities and differences as exemplified in the items listed above.

This study is of interest not only for its findings but for the application to a modern civilized community of a method which was originally developed by the senior author for the study of the social structure of a primitive Australian tribe. The research was conducted by the Committee of Industrial Physiology at Harvard University.

THE SOCIAL ORGANIZATION OF THE WESTERN APACHE. *By Grenville Goodwin. The University of Chicago Press, Chicago.* $4.50. 8¼ x 5⅝; xx + 701; 1942.

This is a solid, authoritative, and very obviously sincere work with a richness of detail which adds rather than detracts from the flow of interest. Most of the material the author obtained from the Western Apache of Arizona themselves, while he lived among them. On the reservation he was able to acquire an intimate knowledge of the day-to-day functioning of the social structure and to listen as well to the stories of a number of old Apache men and women, some of whose lives covered nearly a century and who recalled happenings told them by their parents and grandparents. By the addition of material from documentary and historical sources, the author was thus enabled to trace and compare the social and economic organization of the Apache from the aboriginal life, through the period of early contact with the whites and the uprooting to government reservations, to their present mode of life in a modern reservation community. Reservation life has wrought changes in practically all of their social, cultural and economic institutions, customs, and rituals—kinship practices, marriage, death and burial, children's play, etc. The one exception appears to be religion, for although war chiefs have become a thing of the past, the shamans still function much as they did in pre-reservation days. Apparently the most that the Catholic and Lutheran missionaries have succeeded in doing is to confuse the Apache concerning beliefs in the hereafter. As one Apache put it: "Nowadays we believe that the good people go to a place above and the bad to a place below. No one has ever been to the place above and come back so we don't know just where it is."

Of particular interest are the analyses of the clan organization and kinship systems. These lead "to the definition of a new type of 'phratry' for this region in which clan groups are joined together in 'chain fashion' rather than being sharply segregated." The very detailed observations of the play activities and training of children in their social and cultural setting should be of particular value to students of child development.

Goodwin had planned a series of monographs on various aspects of Western Apache life. With his death at the age of thirty-three, before this book was published, American Anthropology lost a brilliant and promising member.

IRENE MOUND SITE, CHATHAM COUNTY, GEORGIA. *By Joseph Caldwell and Catherine McCann. With a Section on Physical Anthropology, by Frederick S. Hulse. University of Georgia Press, Athens.* $1.50. 10½ x 8¼; xiv + 84 + 25 plates; 1941 (paper).

This is a report of the first extensive excavations of the Irene Mound Site, located five miles from Savannah, Georgia, on the western bluff of the Savannah river. The region was known to the early settlers, and since the civil war sporadic investigations have been carried on. Intensive work commenced during the depression as

part of the Archaeological Project of Works Project Administration.

The large mound from which the site derives its name is 15½ feet high and 160 feet in diameter. A smaller mound, the burial mound, 55 feet in diameter and 2½ feet high, is immediately to the west of the larger mound, the edges of the two overlapping. Two large burrow pits are nearby. Identification of the site with any particular group of Indians was impossible but there is evidence that the last occupation lasted almost to historic times.

The excavations showed that the site was occupied by eight building stages.

The most impressive feature of the Irene site was the large proportion of presumably ceremonial buildings and inclosures, and the relatively small number of possible habitations. Evidently the site was a political or ceremonial center or both for the population of a considerable area. Despite the apparent lack of housing facilities, the large amount of midden indicates that domestic as well as ceremonial activities were carried on.

On the basis of the pottery studies, two main ceramic periods are recognized, an earlier Savannah and a later Irene. The burial mound was begun sometime during the Savannah period. One hundred and six interments were found with many of the bones in good condition and suitable for measurement. A mortuary built during the Irene period was probably used as a repository. Bone measurements show that in their physical characteristics the inhabitants were American Indians similar to those in neighboring regions.

The report is well supplied with illustrations and plates, showing pottery, plan of the buildings, skulls, artifacts of bone and of flint. A bibliography is provided but there is no index.

THE HAITIAN PEOPLE.

By James G. Leyburn. Yale University Press, New Haven; Oxford University Press, London. $4.00. 9¼ x 6; x + 342; 1941.

The Republic of Haiti, one of the smallest of the Latin-American republics, holds much interest for the people of the United States. Its war of independence, fought only twenty years after our own, made it the second free state in the hemisphere and the first independent Negro state in the modern world. The recent nineteen-year American occupation of the country has resulted in a close relationship between the two republics. Unfortunately, however, the average American's knowledge of Haiti has been gleaned largely from sensational works of fiction concerning its early leaders and from over-dramatized accounts of its "Voodoo" practices. The book under review, according well with our present policy of good neighborliness, affords a clear, succinct account of Haitian life and customs without either sensationalism or over-dramatization. The author, on the basis of a personal acquaintance with the country and a firm background of research concerning its history, here presents "a connected story of the growth of its social institutions out of the backgrounds of slavery and French colonial life" and "of the slow shaping of these institutions through the nineteenth century." The political history of the country is recounted in some detail and the influences exerted upon the social structure by the efforts of the great leaders of the early days —Toussaint L'Ouverture, Dessalmes, Christophe, Pétion and Boyer—are critically evaluated. The evolution of the two great "castes", the élite as opposed to the masses, is followed and the lines of demarcation which separate them are traced to their origins. The backgrounds of the religious beliefs of the country, including "Vodun", and the domestic life and politics of the people are fully considered. A final section deals in a most enlightening manner with modern Haitian problems: problems of over-population, national health, and national education, as well as the more intimate problems arising from the "caste" system and present-day color barriers. There is a comprehensive bibliography and a well-planned index.

A scholarly and sympathetic account of the Haitian people, this book will be of the utmost value to all who are interested in our Latin-American neighbors, whether as serious students or as casual visitors.

PROBATION AND PAROLE PROGRESS. *Yearbook National Probation Association Nineteen Hundred and Forty-one. Current Opinion on the Treatment and Prevention of Delinquency and Crime. Papers Given at the Thirty-Fifth Annual Conference of the Association at Boston, May 29–31, and Atlantic City, June 2–4. Edited by Marjorie Bell. The National Probation Association, New York.* $1.25 (paper); $1.75 (cloth). 9 x 6; 470; 1941.

It was in 1841 that John Augustus, a Boston shoemaker, bailed into his custody a poor inebriate brought before the Boston court and thereby gave impetus to the probation movement in the United States. Thus this yearbook, which is a compilation of papers presented at the 1941 meetings of the National Probation Association, appropriately opens with a section of papers on John Augustus, his successors, and a history of the development of the probation movement and the closely related service of parole in this country. The other papers are arranged into five sections. In "The offender in the making" some of the less obvious social causes of crime and delinquency are brought out. The increasing need for case and clinic work is the main theme of the sections on "Trends in juvenile court practices" and "Probation and parole case work," the latter being more concerned with the adult or the family as a

unit. In the group entitled "Aiding the adolescent" Fritz Redl gives a penetrating analysis of adolescent changes as a factor in delinquency, in which he stresses particularly the types of changes, psychological or environmental, which may act either to decrease or to foster chances at therapy. This section also contains three papers on the pros and cons of the Youth Correction Authority Act, and a brief survey of the set-up and procedure of the Borstal System in England and the United States. The last section "Utilizing group situations," again deals with work with children and youth and describes the experiences with a group of maladjusted school children in Buffalo, the Y Rangers Boys' Club in Westchester County, New York, and the citizenship training program of the Boston juvenile court.

FOUR YEARS IN PARADISE.

By Osa Johnson. J. B. Lippincott Company, Philadelphia. $3.50. 9¼ x 6½; 345; 1941.

Five hundred miles north of Nairobi lies Lake Paradise, so named very appropriately by the late Martin Johnson and his wife, who is the author of this book. At this remote and beautiful place the Johnsons had spent four years in recording by moving pictures the practically undisturbed local wild life.

The book tells of the hardships, risks and pleasures encountered in photographing the large game and the natives in the surroundings of the Johnsons' elaborate camp by the lake. Much of their interesting experiences and their many adventures in Africa had already been described in several previous books by Martin Johnson. The present volume by Osa Johnson devotes much space to a woman's interests and activities in a busy life in the wilderness. She recounts in detail how she created a comfortable home, a productive garden, an efficient kitchen, how she entertained guests, attended to her pets, and with it all found time to sit in blinds at night, observing lions and other nocturnal prowlers, or go hunting and fishing with varied success. There is much one can learn from these pages: What to do when an elephant is about to charge, that one is not always safe from lions when riding in a car—as the author found when she had to shoot one old male which sprang and fell across the hood with one foot through the windshield—that there is no such thing as the often-claimed "elephant graveyard," that porcupine quills are excellent for digging out jiggers from under one's toenails, how birds can be cooked to perfection, unplucked and undrawn, if baked in clay, and much other widely varying information.

The volume is enriched by numerous fine photographs showing African landscape, fauna and natives, as well as the author in many different poses and costumes. There is the usual glossary accompanying most recent books on Africa and an index which is too brief for real usefulness.

THE PUEBLOS: *A Camera Chronicle.*

By Laura Gilpin. Hastings House, New York. $3.00. 9¼ x 7; 124; 1942.

Among the most fascinating chapters in American archaeology and anthropology are those dealing with the Pueblos and Cliffdwellers of our Southwest—chapters which cover a period of over a thousand years. The homes of these people have in many instances been remarkably well preserved, or could be restored with justified confidence. There were villages in the valleys very similar to the present day Pueblos' dwellings and there were clusters of houses and towers on mountain tops and in the sides of almost inaccessible cliffs, the houses at times five stories high and several hundred feet long, providing shelter for an aboriginal population much in excess of that of to-day. These homes were fashioned of local stones and timber with crude tools and without mortar, but they were built to endure and designed to harmonize with their environment to perfection.

This book is mainly a collection of over 70 varied and beautifully reproduced photographs, showing the homes of the early Pueblos and the country in which they lived, together with many views from the daily life of their present descendants. Each picture is accompanied by brief, yet ample and instructive comment. A small map is included, indicating the location of some of the more important Pueblo ruins and contemporary settlements. Visitors to New Mexico and the surrounding states will find this little volume a stimulating guide, and everyone interested in early Americans will be delighted with these well-chosen pictures of some of our most ancient as well as most beautiful historic monuments.

CULTURE ELEMENT DISTRIBUTIONS; XVII YUMAN-PIMAN. *Anthropological Records, Volume 6, Number 3.*

By Philip Drucker. The University of California Press, Berkeley. $1.25. 11 x 8½; 91–230; 1941 (paper).

The aim of this study is twofold:

to present a series of comparable data on the "rancheria" groups of the southwestern United States as a part of the University of California program of the culture-element survey of western North America; and second, to establish the cultural position of these tribes in relation to those of neighboring regions. This set of lists is meant to tie in with three previously made: Gifford's survey of the Puebloan and Athabascan Southwest . . . , Stewart's southern Basin survey . . . , and the southern Californian survey by the present writer. . . . .

Data are given from seven Yuman-speaking and four Uto-Aztekan groups. Information was obtained from individuals of these groups. In order to obtain a check on the reliability of this kind of information Drucker compared his data with available literature. He found "the amount of error is reasonably low (I should estimate about 5 per cent of the total entries), and this error is chiefly in matters of minute detail." Points of disagreement have been cited in section "Ethnographic notes on the element list."

The culture element distributions are arranged in tables under the following broad headings: subsistence, material culture, amusements, social culture, individual development, ceremonials, Shamanism, miscellaneous customs and beliefs.

These records form a valuable addition to ethnological data of a comparative nature on Southwestern Indian culture.

ETHNOGRAPHIC BIBLIOGRAPHY OF NORTH AMERICA. *Yale Anthropological Studies, Volume I.*

By George Peter Murdock. Yale University Press, New Haven; Oxford University Press, London. $2.00. $10\frac{3}{4}$ x $8\frac{3}{8}$; ix + 168 + 1 folding map; 1941 (paper).

The present bibliography dealing with aboriginal North America is part of a much larger bibliography that the author has been accumulating for many years past on primitive and historical cultures "with the object, partly of directing distributional and other studies in the classroom, partly of recommending library purchases, and partly of preparing for a projected study which later materialized as the Cross-Culture Survey at the Institute of Human Relations." Murdock has provided teachers and students and especially field workers with a source book of great usefulness.

The plan of classification has been followed which modern anthropologists have found most satisfactory, namely by tribal groups, with an arrangement as a norm

the nationally self-conscious tribes of regions with some measure of political development, e.g., those of the Plains. For regions with less extensive political integration, groups of approximately the same degree of linguistic and cultural homogeneity were formed by arbitrarily uniting a number of tribelets or local groups, usually under the name of one of them.

Fifteen geographical areas are recognized for all of North America as far south as Tehuantepec, with the tribal groups numbering 277. A carefully-prepared, loose folding map shows the distributional areas.

INDEX OF THE AMERICAN JOURNAL OF PHYSICAL ANTHROPOLOGY. *Volumes I–XXII; 1918–1937. Part Two: Literature. Instituto Panamericano de Geografia e Historia, Publicacion Num. 45. Compiled by W. Montague Cobb under the direction of Aleš Hrdlička. Antigua Imprenta de Murguia, Mexico, D. F.* $8\frac{7}{8}$ x $6\frac{1}{2}$; 394; 1941 (paper).

The rapid growth of the world's scientific literature makes it steadily more difficult to know what has become known, to use what information is available and thus to benefit fully by the labors of one's past and present colleagues. Our technical journals with their wide-ranging contents would become mere burial places for newly gained knowledge without an adequate index for finding readily everything that has been recorded in their pages.

Cobb has performed a labor of love in undertaking the arduous task of indexing in great detail the first twenty-two volumes of the *American Journal of Physical Anthropology*. The previously issued part of this index dealt with the original contributions in the Journal. The present, second part is devoted to the reviews in the journal of original papers published elsewhere. These reviews, which had been selected quite at random, are unfortunately very far from representing the world's contemporary literature on physical anthropology. The latter has been covered much more completely in several other journals, at least as far as listing titles and classification of contents is concerned. The usefulness of this index is also impaired by the fact that quite evidently there has been no proofreading, since printer's errors in foreign-language titles occur with intolerable frequency. In one instance there are nine errors in one title and it is difficult to discover the true meaning.

NORWEGIAN-AMERICAN STUDIES AND RECORDS. *Volume XII.*

By the Norwegian-American Historical Association. Norwegian-American Historical Association, Northfield, Minnesota. $2.00. 9 x 6; vii + 202; 1941.

Nine articles by as many authors are included in this book dealing with various social and cultural aspects of Norwegian-American history. The papers which probably will be of most interest to the sociologist or human biologist are the first two, in which change in surnames and the development of the Norwegian folk narrative in America, respectively, are utilized in tracing the migration of ideas and traditions from the Old World to the New. The other articles are more in the narrative or reminiscent manner. Two describe emigrant voyages in the 1840's and 1850's. There is one article on the pioneer life in Texas and two on the founding and development of the Norwegian-American press. Another chapter, by a life-long friend of Ole Edvart Rølvaag, is devoted to interesting recollections of the background and boyhood in Norway of the author of "Giants in the Earth." The last article is also biographical. It tells the story of Ole Evinrude and the outboard motor. Appended is the most recent install-

ment of a series, compiled for the Norwegian-American Historical Association, of publications by, about, or of interest to, members of the Norwegian element in the Americas.

OZARK COUNTRY.

By Otto Ernest Rayburn. Duell, Sloan and Pearce, New York. $3.00. 8⅛ x 5⅜; ix + 325; 1941.

Rayburn prefers to restrict the Ozark country to the highland region of the southern half of Missouri, the northwestern part of Arkansas and a few counties in eastern Oklahoma. This empire of hills and valleys and occasional stretches of rolling prairie occupies an area approximately 60,000 square miles. Of the nearly one million people living in this region only about one-fifth live in the cities and larger towns, another fifth in the "favored rural sections" and the remainder in regions where they "must struggle against adverse economic conditions." This last group has, more than the others, lived in a world apart and has preserved the speech and customs of the early pioneer settlers. Here Rayburn finds the richest material for his book. He has given us a rather full and picturesque account of the family life and customs of these more secluded hillsmen of the Ozarks and recorded it with sympathy and real understanding. He is particularly well fitted for the task, having spent much of his life in close association with these people. Ozark Country is the fourth of the American Folkways books edited by Erskine Caldwell.

FROM CRETIN TO GENIUS.

By Serge Voronoff. Alliance Book Corporation, New York. $2.75. 9¼ x 6½; 281; 1941.

This book, designed for popular consumption, represents an effort to delve into the nature of that rare phenomenon, a genius. The author is known for his discovery of rejuvenation through the process of grafting monkey glands in the human body. The "creative process" and the origin and "struggles" of genius are considered as manifested in certain great men throughout history, e.g. musicians, scientists, mathematicians, poets, artists, philosophers, etc. Many interesting anecdotes are related, each as illustrative of some particular point; documentation, however, is regrettably lacking. Because of the author's complete lack of emphasis on the rôle of the environment in developing the outward manifestations of inborn hereditary aptitudes, the impression is gained that environment has little or no influence. There are, furthermore, many loose statements, such as the following: "Genius possesses not only wondrous aptitude, it is simultaneously endowed with *knowledge* which heredity, often a distant heredity, has bequeathed to it."

From Cretin to Genius makes the mistake often made by books dealing with the sensational. It tries to be sensational itself.

DEAD MEN DO TELL TALES.

By Byron de Prorok. Creative Age Press, Inc., New York. $3.50. 9¼ x 6; xiii + 328; 1942.

This is not so much the tale of dead men as it is the tale of live men—the primitive, savage, beastial, very-much-alive natives of Central Africa. Although the author began his trip through Egypt and Ethiopia with the aim of studying prehistoric cultures at various excavation sites, he seems to have been lured on to find out more and more about the primitive cultures of contemporary Africa, and less and less about prehistory.

The author's eye-witness accounts of the ceremonial practices of many dark and secret cults in the heart of Africa; his hair-breadth escapes from the jaws of certain death; and his glowing descriptions of the fauna, flora and terrain of equatorial Africa contribute alike to the suspense of this fascinating story. The modern version of African slave trading, and the political turmoil resulting from the attempted European domination of Ethiopia seem to have impressed the author as much as his prehistoric finds. In the field of pure adventure, the book contributes considerably more than in the field of archaeology.

STUDIES AND ACTIVITIES IN BIOLOGY.

By Chapin W. Day and Margaret Ritchie. Edited by John W. Ritchie. World Book Company, Yonkers-on-Hudson, N. Y. 80 cents. 10½ x 8; vi + 218; 1942 (paper).

This study and laboratory guide has been designed to accompany Ritchie's *Biology and Human Affairs* (cf. Q. R. B., Vol. 17, No. 1) for high school students.

The emphasis here is to get the biology class away from a checking of facts to a discussion of ideas and principles and their application in the world in which the student lives. A variety of experiments and activities are outlined, in completing which students will deal first-hand with a wide variety of living material. All are pointed to an understanding of biological principles.

BULLETIN DER SCHWEIZERISCHEN GESELLSCHAFT FÜR ANTHROPOLOGIE UND ETHNOLOGIE 1941/42. *18. Jahrgang. Containing the following papers: Vom Charakter des höchsten Gottes der Azteken*, by Hans Dietschy; *Die Skelettfunde von Holderbank im Kanton Solothurn*, by

Lucia Graf; *Skelette von Bonaduz aus dem Ausgang der La Tène-Zeit*, by Otto Schlaginhaufen.

Edited by Otto Schlaginhaufen. Büchler and Company, Bern. 9 x 6¼; 21–69 + 8 plates; 1942 (paper).

ZOÖLOGY

THE PIGEON.

By Wendell Mitchell Levi. With a Preface by Oscar Riddle. R. L. Bryan Company, Columbia, S. C. $10.00. 11 x 8½; xxxii + 512 + 2 colored plates; 1941.

This book is written by a lawyer who "since early boyhood has raised pigeons and found in them a hobby which has brought relation coupled with stimulation to such a degree as to color and enhance every phase of my life." This quotation sets the spirit of the book. From the first chapter on the reader is filled "with the desire to learn more about a bird, which unlike any other single living creature, has won the interest, affection and veneration of mankind throughout the history of civilization." The pigeon is the emblem of peace as well as an effective means of liaison in war! Of all birds, according to a Philippine legend, only the dove understands the human tongue.

The second chapter, the longest in the book, deals with the breeds and varieties of pigeons and their probable origin. To all, except the pigeon fancier, their great number is impressive—almost equal, it would seem, to the number of breeds and varieties of the domestic fowl.

The chapters on anatomy and physiology are overflowing with information yet contain little of the more strictly technical literature on these subjects. Among the most interesting topics considered are how pigeons drink, whether each pair of eggs in a clutch produces a cock and a hen (a popular belief for over 2000 years), and the function of the ductless glands, particularly the hypophysis.

Chapter V first traces the origin and progress of the science of genetics—variation and inheritance. This is followed by an extensive list of familiar names of men who have made contributions, theoretical or experimental, to pigeon genetics. The more technical phases of the subject are dealt with quite adequately by the author. These include inheritance of color and morphological characters, such as "crest and hood," silky feathering, scraggly, webfoot and clumsy, and sex linkage. The chapter ends with a useful table of genetic characters.

The problem of pigeon behavior is treated in a somewhat popular manner, owing largely to the fact that the behavior mechanisms are not too well understood. Descriptions are given of the phenomena of courtship, mating for life of cock and hen, nest-making, sense of location and homing ability.

The last six chapters deal respectively with Practical breeding, Diseases, Parasites and pests (their treatment and control), Feeds and feeding, Housing (ancient and modern), Commercial squab production, and The pigeon fancy (exhibition, racing, training, organizations, etc.). The book ends with an extensive bibliography and a complete index.

Considered as a whole the book is a fascinating one, combining both popular and technical information. It will appeal to the pigeon fancier and the layman, and to the scientist who needs to know much about pigeons before experimenting on them.

LICE. *British Museum (Natural History) Economic Series No. 2A.*

By John Smart. British Museum (Natural History), London. 6d. 8¾ x 5½; 32; 1942.

This pamphlet, listed in the "Economic pamphlets, dealing with the application of natural science to practical affairs," has probably been issued with the purpose of making available to the English people the best means of combating a pest which can easily be acquired under the crowded conditions of bomb shelters or unusual living conditions such as exist in England today. It is remarkable for its clear and simple style and interesting manner of presentation.

The different kinds of lice are distinguished, but chief attention is given to the three kinds of lice infesting Man (head, body, and pubic). While head and body lice have distinguishing characteristics, the two forms can be interbred. When head lice are bred continuously for several generations on the body they tend to assume the characteristics of body lice. It would seem that "Head and Body Lice are but two extremes of one species and that examples showing intermediate grades may occur."

Clear descriptions are given of the life history of the three kinds of lice of which man is host, manner of infestation, and the effects of habits of the host. Some individuals who are insensitive to lice may act as carriers. Three diseases are borne by the louse: (1) Typhus which is found in many parts of Europe, particularly Eastern Europe; it occurs in the United States in a mild form known as Brill's Disease; (2) Trench Fever which appeared during the 1914–1918 war, mainly among soldiers, but disappeared after the war; and (3) Relapsing Fever which is widespread but seems to be absent in Western Europe and the United States.

The last part of the pamphlet is devoted to the prevention and treatment of lousiness. With due regard to the desire that some readers may have to pursue this subject further Smart has provided a brief bibliography.

A FISHERY SURVEY OF IMPORTANT CONNECTICUT LAKES. *Bulletin No. 63. 1941. State of Connecticut Public Document No. 47.*

By the State Board of Fisheries and Game Lake and Pond Survey Unit. State Geological and Natural History Survey of Connecticut, Hartford. Free in Connecticut; $1.00 outside of Connecticut. 8¾ x 6; 339; 1942.

This report presents the results of a fishery investigation of 47 Connecticut lakes and ponds, and includes data gathered over a period of three years (1937, 1938, 1939). The purpose of the Connecticut lake and pond survey has been to gather fundamental information on the physical, chemical, and biological conditions in each body of water; to secure knowledge of the life history and habits of each important species of fish; the kind, extent, and probable effect of fish parasites; as well as other biological data. Numerous ways and means by which fishing may be improved are presented. Since the aim of the report is partly to give informative items of particular interest to sportsmen, the language used has been kept as simple and non-technical as possible.

The material discussed in the survey includes: management methods as applied to pondfish restoration, the lake as an environment for fish, procedures in a limnological survey, the life histories of various Connecticut fishes, the food and the growth of fishes, parasitism and the fish crop, and parasites in some Connecticut fishes as compared with other states. The appendix contains helpful information on: pondfish stocking, technical and analytical methods, and a summary of information and recommendations for the improvement of fishing. Extensive lists of the literature cited have been placed at convenient points in the book. The report is well illustrated with numerous photographs, drawings, and tabular and graphical material but there is no index. Much of the information herein presented will be of practical value in any region in the United States.

THE SEASONS AND THE FISHERMAN: *A Book for Children. By F. Fraser Darling. Illustrated with Drawings by C. F. Tunnicliffe. Cambridge: at the University Press; The Macmillan Company, New York.* $1.75. 8¾ x 6⅝; viii + 70; 1942.

The author of this book has a story to tell and knows how to tell it. Although his language is so simple that any child could read and understand it yet it is not in any sense childish language. If an adult should read the book to a child their enjoyment of it would be equally divided.

The author has done a great deal more than merely follow the fishermen through the year. He explains why certain fish appear only in certain seasons, and this involves a discussion of "food chains," and the opening chapter which deals with these covers the evolution of the sea and its plankton and is just as well written as the rest of the book. Also, the story of the deep sea fish, which the ordinary fisherman never sees, the life history of the eel, about which he knows nothing and cares less, and the ichthyologist's method of determining the age of a fish by examining its otoliths add much to the interest of the story.

Finally, one must add a word of appreciation of the preface. Some children seem to go through a period of development in which they seem to enjoy inflicting pain on animals. It is difficult to explain to such children why they should not indulge in cruelty when they see how it is involved in gathering food for mankind. But it is difficult to imagine any one reading this preface and not feeling more kindly disposed toward the animals of the sea.

The typography of this work is superior to the average and the artistic illustrations are superb.

BEETLES OF THE GENUS HYPERASPIS INHABITING THE UNITED STATES. *Smithsonian Miscellaneous Collections, Volume 101, Number 6. (Publication 3642.)*

By Th. Dobzhansky. Smithsonian Institution, Washington D. C. 35 cents. 9¾ x 6¼; 94 + 6 plates; 1941 (paper).

The ladybird beetles of the genus *Hyperaspis* are herein completely revised and new forms are described. No extensive work on this genus has been attempted since the publications of the late Colonel Casey who described well over half of the species. A large number of Casey's descriptions are now relegated to synonymy but the great majority are shown to be valid. Whenever possible, the genitalia were examined to establish specific distinctions.

The center of dispersal of this generic group was in Central and South America, whence it has spread to the South and Southwest of the United States. As a result, the majority of the forms are found in this area and only a few have reached the eastern and northern boundaries of the country. The writer holds that his results are still tentative because of the lack of specimens from the center of dispersal, but as far as actual specimens will permit him, he recognizes 72 species, of which eight are new; 31 subspecies, 11 of which are new; and six varieties, three of which are new; grouped into 14 (13 in the text due to a typographical error) categories of closely related species.

Each form is described, genitalia included whenever known, and the geographic distribution carefully listed. There are six plates which give details of the structure of the genitalia and of the elytral patterns. Many of the species are economically important as predators on scales and other insect pests, consequently such a thor-

ough revision of one of the largest and the least known genera in the family Coccinellidae is of considerable value.

COLLEGE ENTOMOLOGY.

By E. O. Essig. The Macmillan Company, New York. $5.00. 9¼ x 6; vii + 900; 1942.

Insects play an important part in man's economic life. While some are destructive and the bearers of disease, by far the greater number are important in many ways, directly and indirectly, for man's existence, besides being of great biological interest. In the cross-pollination of plants they play an important rôle, they furnish food for birds and fishes, and they even are destroyers of obnoxious members of their own group.

To those acquainted with Essig's *History of Entomology* and *Insects of Western North America* this volume requires no introduction. Although much broader in scope than the latter book, by no means have all the half million described species of insects been included. The selection has been made on the basis of long association with the human race, some peculiarity in form, size, color or habits, and interesting and typical examples of family. The present volume has been written as a text, on traditional lines, but Essig has succeeded in making it extremely interesting. The volume has a wider usefulness, however, than in the classroom. The layman, with an interest in natural history, particularly in insect life, who lives or travels in out of the way places would do well to include the volume in his library, however limited that may be. The arrangement of the keys is excellent and easily mastered; the 308 figures are carefully chosen and well executed. Selected references accompany each chapter and a general bibliography and indexes of authors and subjects are provided. At the back is given a map of the zoogeographical regions of the world.

A MONOGRAPHIC REVISION OF THE MEXICAN WATER BEETLES OF THE FAMILY ELMIDAE. *Novitates Zoologicae, Volume 42, No. 2.*

By H. E. Hinton. British Museum (Natural History), London. 15s. 11¼ x 7¾; 217–396; 1940.

An unorthodox procedure in systematic entomology is used to define and distinguish the genera of beetles studied in this volume. Use is made of the internal anatomy of the alimentary canal, male and female reproductive organs, and the central nervous system. In most cases the anatomical studies show good correlation with external morphological criteria and in some where the latter fall down they reveal relationships not otherwise clearly understood. For instance, the genus *Cylloepus*, which seemed to consist of a homogeneous assembly of species, is shown on the basis of the internal anatomy to consist of two very distinct groups. The external genitalia are also used to compare species. As a result of all this careful work most of the species are well allocated to their systematic positions.

Keys and complete descriptions make this monograph an exceedingly good one. The writer eschews comparative terms as "broader than long," "coarse," "fine," etc. Instead he uses actual measurements, even of the surface punctures; this procedure is to be highly recommended. Sexual differences are also described—a feature that is so often overlooked—and whenever known, the larval and pupal stages.

Statistical analyses of the measurements of the species were found to have limited application. Differences between two species were often less than those found in a single species at different altitudes.

THE PLANT BUGS, OR MIRIDAE, OF ILLINOIS. *Bulletin of the Illinois Natural History Survey, Volume XXII, Article 1.*

By Harry H. Knight. State of Illinois, Urbana. $1.25. 9⅞ x 6¾; 234; 1941 (paper).

The Miridae, or plant bugs, rank as one of the most important groups of insects destructive to plant life in Illinois. Except for a few predacious species they suck the juices from plant leaves. Knight was put in charge of the survey which commenced in 1930 and continued through 1937. He identified the species and wrote the present report, but many others took part in the project.

The collection of Miridae numbered over 20,000 specimens and came from every part of the state. Collections were made at different seasons of the year over the same territory in order to get certain species which might be restricted to certain periods. The list of known Miridae of Illinois now includes 330 species, but since other species and varieties occur in the entire general region in which Illinois is situated and will probably find their way into the state, over 100 other species have been added to the list. In North America, north of Mexico, about 1500 species of Miridae are known.

Preceding the descriptive part, Knight devotes a section to the biology, distribution and habitat, preference, economic status and control, and taxonomy of the Miridae. The volume includes many excellent figures, a group of illustrations showing habitat, a list of host plants, a bibliography of 146 titles, and an index.

CATS AND ALL ABOUT THEM.

By L. H. Fairchild and Helen C. Fairchild. Introduction by Belle J. Benchley. Orange Judd Publishing Company, New York. $2.00. 7⅞ x 5½; 231; 1942.

The authors of this book are a unique combination of cat lover and breeder and practicing physician and surgeon. They have recorded the results of their wide experience, with practically every breed of cat, with expertness and real understanding. The book is based to a certain extent upon the inquiries of hundreds of visitors to their cattery and as a result contains, along with the more intricate phases of care and management, those every day things about cats and kittens which writers so frequently take for granted and neglect to set down.

Topics such as successful methods of selection, breeding, management, housing, training and habits of cats are taken up in some detail. Descriptions of common ailments, their recognition and medication, together with the treatment for disease and parasites are also fully treated. Numerous photographic illustrations of various breeds of cats accompany the text.

REVISION OF THE NORTH AMERICAN MOTHS OF THE FAMILY OECOPHORIDAE *with Descriptions of New Genera and Species. Proceedings of the United States National Museum, Volume 90, No. 3107.*

By J. F. Gates Clarke. Government Printing Office, Washington, D. C. Free. 9½ x 6; 33 − 286 + 48 plates; 1941 (paper).

To the Oecophoridae belong several species that are of economic importance, some forms that feed on stored products, such as dried foods, bulbs and tubers, scavengers that feed on the refuse occurring in the nests of mice and birds, and forest forms that attack the beech, oak, pecan and hickory. The majority of the Oecophoridae are leaf and flower feeders in the larval stage.

In this revision are listed 22 genera and 117 species of which 6 genera, 19 species, and 1 race are new. Detailed descriptions are given for each form, place of type, type locality, food plants and distribution. A series of fine drawings (48 plates with 288 figures) illustrate distinctive features. An index to the genera, species, and localities is provided, also an index to food plants.

OUR AMERICAN GAME BIRDS.

By Van Campen Heilner. Foreword by Colonel Theodore Roosevelt. Paintings and Drawings by Lynn Bogue Hunt. Doubleday, Doran and Company, New York. $5.00. 13 x 9¾; xi + 178 + 19 plates; 1941.

As an account of the habits, migration routes, breeding and wintering grounds of the game birds of the Western Hemisphere this book serves its purpose as a reference work for the sportsman. Unfortunately its large size precludes its use as a field manual. There is some very sound advice to the hunter concerning the haunts and habits of many of the birds listed which should aid him in obtaining his bag limit. There are nineteen color plates by Lynn Bogue Hunt. The extremely gaudy colors in the background of these paintings detract a great deal from the coloration of the birds themselves.

The appendix contains much valuable information about hunting dogs, bird flight and waterfowl regulations. There is also a useful field guide, and several maps showing the ranges and migration routes of many of the birds described.

WORLD OF BIRDS.

By Eric Parker. Longmans Green and Co., London and New York. $3.00. 7½ x 4¾; vii + 295; 1941.

To the very large number of popular books written about wild birds both in this country and England we have another to add. Since the subject matter of such books is very much the same (usually being a description of the appearances and habits of birds with which the author is somewhat familiar) originality of treatment is rare. Not so, however, with Parker's book. We have here a most refreshingly original treatment of English bird life written in a very personal style. Although the author is somewhat amusingly poetic in some of his descriptions, this in no way detracts from the general interest which the book will have for many readers. The accuracy with which the subject matter is treated and the critical attitude the author takes in his discussions of the habits of birds, about which different beliefs exist, are particularly commendable.

AMERICAN WATER BIRDS: *Also Hawks, Owls and Game Birds.*

By Maitland A. Edey. With Colored Plates by Louis Agassiz Fuertes. Random House, New York. $1.00. 11 x 8¾; 72 + 29 plates; 1941.

This little book has been written as a companion volume to *American Songbirds* by the same author. Like the latter it has been prepared as an aid to those just starting on their study of bird life. The most valuable feature of the book is its twenty-seven colored plates of birds by the dean of all bird artists, Louis Agassiz Fuertes. Considering the low price of the book, these illustrations are rather accurate reproductions of the original paintings of Fuertes. Included with the plates are simple, accurate, though very brief descriptions of the birds and their habits. All of the familiar water birds of the Eastern and Central United States and Canada, as well as representative hawks, owls, and some upland game birds constitute the subject matter of the book.

THE FORAMINIFERA OF THE TROPICAL PACIFIC COLLECTIONS OF THE "ALBATROSS," 1899–1900. *Part 3, Heterohelicidae and Buliminidae. United States National Museum Bulletin 161.*

By Joseph Augustine Cushman. Smithsonian Institution, Washington, D. C. 20 cents. 9 x 5⅞; v + 67 + 15 plates; 1942 (paper).

A third part of a work describing and illustrating the Foraminifera of the tropical Pacific collected on the *Albatross* survey. Part 4 will complete the work and will take up in systematic order the families beginning with the Rotaliidae.

Cushman finds that the number of distinctive species in this area is large. "Some interesting relationships have been noted in these faunas in which are living representatives of species known hitherto only from the late Tertiary of other regions."

Twenty-nine tables give the locality, depth, bottom temperature, character of bottom, and occurrence. The 15 plates show many views of the forms described.

OYSTERS HAVE EYES: *or the Travels of a Pacific Oyster. By Eldon Griffin. Wilberlilla Publishers, Seattle.* $1.00. Discount of 25 per cent in quantities of 25 or more. 9¼ x 7⅜; 53; 1941 (paper).

Sifting through the verbiage of this popularized account of the Pacific oyster—the oyster is called Oliver—we find some interesting general information concerning oysters and the oyster business in the State of Washington. Apparently the oyster beds will suffer from the Pacific war since "the high-grade seed, or spat, on which the Pacific-Oyster industry depends for its life has come from Japan. Scores of Americans, particularly in the State of Washington, have invested hundreds of thousands of dollars in land and equipment for the use of which the supply of imported seed has been essential."

A LABORATORY MANUAL FOR ELEMENTARY ZOOLOGY. *By W. Byers Unger and C. E. Mority. Ginn and Company, Boston.* $1.25. 10⅜ x 7¾; iv + 106; 1042.

This manual has developed out of a series of laboratory directions used in a one-semester, elementary course in zoology at Dartmouth College. Certain vertebrate systems—digestive, respiratory, and reproductive—are presented as demonstrations so that detailed laboratory instructions are unnecessary. A very good introduction to the use of the microscope is given and a glossary of terms frequently employed. Blank right-hand pages are provided for student drawings.

LABORATORY DIRECTIONS IN PRINCIPLES OF ANIMAL BIOLOGY. *Fifth Edition. By A. Franklin Shull with the Collaboration of George R. Larue and Alexander Ruthven. McGraw-Hill Book Company, New York.* $1.00. 9 x 6; ix + 102; 1942.

No fundamental change has been made in the present edition of this laboratory guide. In the main, the revisions have been made to conform to the changes in the recent fifth edition of *Principles of Animal Biology* (cf. Q. R. B., Vol. 16, p. 492) which the laboratory guide was designed to accompany.

OCCASIONAL PAPERS OF THE MUSEUM OF ZOOLOGY, UNIVERSITY OF MICHIGAN. *Nos. 449–456. A Race of the Blue-hooded Euphonia from Sonora,* by A. J. van Rossem; *The Pygmy Owl of the District of Soconusco, Chiapas,* by Pierce Brodkorb; *Notes on Salamanders with Descriptions of Several New Forms,* by Sherman C. Bishop; *Some New Snakes from Guatemala,* by L. C. Stuart; *A Race of Woodhewer from the Alto Parana,* by Pierce Brodkorb; *Geographic Variation in Mesogonistius Chaetodon (Baird), with Description of a New Subspecies from Georgia and Florida,* by Reeve M. Bailey; *Descriptions of Two New Species of Plectrohyla Brocchi with Comments on Several Forms of Tadpoles,* by L. C. Stuart; *The Pleuroceridae of the Atlantic Coastal Plain,* by Calvin Goodrich.

University of Michigan Press. Ann Arbor, Michigan. 9 x 6; No. 449, 2; No. 450, 3; No. 451, 21 + 2 plates; No. 452, 6; No. 453, 2; No. 454, 5; 1941: No. 455, 14; No. 456, 6; 1942. (Paper.)

DEVESCOVINID FLAGELLATES OF TERMITES. II. *The Genera Caduceia and Macrotrichomonas. University of California Publications in Zoology, Volume 45, No. 2.*

By Harold Kirby. University of California Press, Berkeley. $1.00. 10¼ x 6¾; 93 – 166 + 12 plates; 1942.

BOTANY

A SHORT HISTORY OF THE PLANT SCIENCES. *By Howard S. Reed. Chronica Botanica Company, Waltham, Massachusetts; G. E. Stechert and Company, New York.* $5.00. 10¼ x 6⅝; 320; 1942.

Volume VII of "A New Series of Plant Science Books," edited by Franz Verdoorn, is an account by Reed of the development of plant sciences from earliest records to the present time. The condensation of this enormous subject matter into a little over 300 pages is in itself an achievement. Reed, however, has succeeded far beyond this goal. He has presented in brief form not only historical accounts of the contributions of practically all principal botanists of the past but has included sidelights on their personalities and the general atmosphere of the times in which they worked.

The first chapter gives an outline of four stages in the

development of plant sciences from the period of "Accumulation" of information through "Verification" and "Classification" to the last period of attempted "Interpretation". Thus he traces the growth of botany from the times of isolated observations to the present trend of organization of plant sciences on an international scale.

The next seven chapters deal with epochs of progress and partial retrogression from civilizations of antiquity up through the Renaissance period with the rise of experimental, natural science in western Europe and its progress to the end of the 18th century. The attention to contemporaneous and earlier Asiatic, particularly Chinese, agricultural achievement and to the development of crop plants and gardening on the American continents is of special interest.

In his account of the tremendous advances since the beginning of the 19th century the author has fortunately chosen to present the subject matter in topic form. Chapters 9 to 19, inclusive, trace the developments leading up to and constituting the separate fields entitled: plant-geography, -morphology, -cytology, water economy of plants, the fixation of carbon, the assimilation and fixation of nitrogen, plant nutrition, mineral constituents in metabolism, mycology and plant pathology. These chapters are more than historical accounts of pioneering investigators and their findings. They form an integrated picture of what the main problems were, what has been accomplished and thus point the directions in which present work leads. They are written with a mature judgment of the subject as a whole and with an insight into functional relationships in plants rarely found associated with historical treatments. These chapters, therefore, contain descriptive material freshened with the experimental viewpoint and reflecting the vital qualities in botany to an extent which will stimulate interest and admiration on the part of uninitiated and advanced students alike. The text might have been further enlivened by a few representative experimental results shown in tabular or graphic form. The book does contain, however, 37 illustrations varying in kind from reproductions of early manuscripts, texts and drawings of plants and tissues, to etchings of some famous botanical institutions and gardens.

Naturally, as the author points out, it is not possible to cover all that has been accomplished in botany in a book of this size. The choice of material and topics has been guided by the author's own interests as well as by considerations of treatments already available on certain topics which have undergone recent and exceptionally rapid development. This has imposed certain limitations from the historian's point of view but has added unity and direction to the book, which to most readers will be far more significant and desirable. A list of references to original papers and to more complete treatises on specific subjects is appended to each chapter.

A distinctive quality of the book is its placing of emphasis. Scientific historical accounts are often of two extreme types. One is so noncommittal and unorganized that the average reader gets lost in technicalities. The other, popular, type exaggerates the importance of a few individuals upon whose shoulders is placed entire responsibility not only for ideas and generalizations but also for detailed elaboration of all accomplishments connected with their times. This procedure fails both on points of accuracy and continuity of progress. The present book strikes a happy balance between the two types. It conveys admiration and due credit to outstanding men but includes kindly rebuke for their shortcomings properly flavored by the author's own evaluation of specific contributions and contributors. The last chapter gives his list of 50 significant names in the history of botany judged on status as discoverers, classifiers, specialists and exponents of botanical knowledge. Most important in this connection is the fact that though the book deals mainly with individual contributors, the subject matter rather than personalities is the central theme throughout.

The book is intended primarily for the orientation of graduate students in botany. For this purpose it should serve admirably and will fill a great need. The simple style and treatment of a vast fund of information will recommend this book to a much wider audience as well.

A Symposium of the Structure of Protoplasm. *A Monograph of the American Society of Plant Physiology. Edited by William Seifriz. Iowa State College Press, Ames, Iowa.* $3.00. 8¼ x 5¼; vi + 283; 1942.

This volume represents the first of a series of monographs to be published under the auspices of the American Society of Plant Physiologists. As originally planned, the symposium, of which the present volume is a record, was intended to bring together biologists, physicists, and chemists in the discussion of protoplasmic structure. Although an unfinished paper by Freundlich and short communications by Astbury and Meyer are the only direct contributions by physicists and chemists in the strict sense, the influence of these fields is very evident in most of the papers of the symposium.

On a molecular level, papers by Moyer and Sponsler and Bath deal with the configurations found in protoplasm, and the forces that may be involved in the various types of aggregation observed. Actual experimental evidence in this field is not abundant, but some very promising studies have been made, particularly X-ray studies of the configuration of protein chains and the distances involved in various molecular arrangements.

A large part of the monograph is devoted to various aspects of the sol $\rightleftarrows$ gel transformations so important in protoplasmic activity. In Freundlich's paper this

subject is taken up from the standpoint of the behavior of well-defined colloidal systems *in vitro*. This approach does much to clarify interpretations of observed protoplasmic behavior.

Kamiya, in an interesting paper, presents a method by which he has been able to measure the magnitude of the motive force producing protoplasmic streaming, a measurement which had not previously been made. He finds that this force fluctuates rhythmically, and by means of Fourier analysis he has been able to resolve the curves obtained into several harmonic components of suitable amplitudes and frequencies. Only a small amount of work has been done with this method, but the findings must be considered in any interpretation of the forces involved in protoplasmic motion.

This monograph is probably the most complete discussion of protoplasmic structure now available, and each paper is accompanied by a bibliography of pertient literature, which adds to its value. In a few cases the picture may have been somewhat obscured by excessive reference to outmoded cytological data, but the general emphasis is on advanced physical-chemical methods which are the basis for so many recent advances in this field. As in any treatise which deals with the border line between established fact and theory, many hypotheses are advanced with little exact experimental backing. However, these represent the ideas of many of the foremost workers in the field, and should prove helpful in guiding further thought and experimentation on these problems. The book should be of interest and value to everyone interested in fundamental biological problems.

AN HERBAL [1525].

Edited and Transcribed into Modern English with an Introduction by Sanford V. Larkey, and Thomas Pyles. Scholars' Facsimiles and Reprints, New York. $3.50. 9 x 5¾; xxiv + 86; 1941.

Agnes Arber, in her interesting book, *Herbals: Their Origin and Evolution*, reviews the evolutionary period of the herbal, covering about 200 years (1470–1670) after the discovery of printing when there was much activity in the production of such works, many of them based on much earlier manuscripts. The present *Herbal* falls within this period. Arber considers it "possible that this book may have some claim to originality but it is more probable that it is derived from an unknown mediaeval manuscript dealing with herbs." Larkey and Pyles believe that "[Eleanor Sinclair] Rohde probably comes nearer the truth when she writes, 'it gives the impression of being a compilation from various sources, the author having made his own selections from what pleased him most in the older English manuscript herbals.' . . . If the work has any single source, that source was itself ultimately a compilation, we may be sure, the compiler having taken what seemed to him good and useful wherever he found it. There is, as a matter of fact, internal evidence of two different ultimate or immediate sources. . . ."

The Herbal, in quarto volume, in black letters, came from the press of one Richard Bankes—"Imprinted by me Richard Bankes, dwelling in London, a little from the Stocks in the Poultry, the twenty-fifth day of March. The year of Our Lord 1525." The first book appearing in England devoted exclusively to herbs, it bears on the title page "Here begynnyth a newe mater, the whiche sheweth and treateth of ye vertues & proprytes of herbes the whiche is called an Herball." Only two known copies now exist; one in the British Museum, from which the Larkey-Pyles facsimile has come, and one in the Huntington Library, San Marino, California. Other editions followed the first issue and the volume was probably widely read and the countryside diligently searched for many plants that were not regularly cultivated.

The herbs are listed alphabetically in 207 chapters, each dealing with a particular herb. Some chapters are only one line in length, others run to two or more pages. The terms that seem to occur most frequently are "this herb is hot and dry", or "cold and dry", or "hot and moist," or "cold and moist." Mostly the virtues of the herbs are in their effect on the digestive tract and the internal organs, but the same herbs when applied externally, either alone or in mixtures, have the power to cure many ailments.

We quote briefly some of the methods of treatment which are given:

'Also, if this herb [wormwood] be pounded with the gall of a bull, and afterward put into a man's eyes, it putteth away all manner impediments of the sight." ". . . take the flowers of rosemary and make a powder thereof and bind it to the right arm in a linen cloth, and it shall make thee light and merry. . . . Also, take the leaves and put them into a vessel of wine, and it shall preserve the wine from tartness and evil savor, and if thou sell that wine thou shall have good luck and speed [success] in the sale." "Also, the juice of onion tempered with any liquor is good to drink for any man that hath lost his speech." Mustard "comforteth the stomach" as it sometimes has in modern times.

The authors have produced a scholarly volume, thoroughly documented. It will interest botanists, herb growers, physicians, and the book collector.

CLIMATE AND MAN. *Yearbook of Agriculture, 1941. United States Department of Agriculture. Government Printing Office, Washington, D. C.* $1.75. 9 x 5¾; xii + 1248; 1941.

Among the environmental factors influencing man's well-being, climate undoubtedly ranks first in that it determines his distribution and controls his movements over the earth's surface, it regulates to a great extent

his agricultural and industrial economy, and it confronts him with some of the greatest problems with which his ingenuity has to cope. Although man still abides by the profound observation of Mark Twain in that everybody talks a lot about the weather but nobody does much about it, the fact remains that he is now able, in some measure at least, to meet the hazards of flood, drought, dust storm, and other climatic aberrations as never before in the history of his race.

In this 1250-page treatise, the Department of Agriculture has brought together all the pertinent data concerning climate as related to agriculture in the United States. In the early sections of the book are found detailed accounts of climate and weather as they affect (1) our important fruit, forest, grain, truck, and livestock production; (2) the common diseases of domestic plants and animals; (3) soil and water conservation; and (4) flood control and irrigation farming. A short middle section of the volume is devoted to a discussion of the scientific basis of modern meteorology and weather prediction under such headings as wind directions, ocean currents, atmospheric pressures, cloud formations, and daily as well as long-range forecasting. The latter portion of the yearbook is concerned with (1) the climates of the world, and (2) the climates of the different states of the U. S. A. The discussions of the climates for each of the states include many maps and tables showing the mean monthly, the mean annual, and the average seasonal precipitation, the earliest and latest frost dates, and the average January and July temperatures for the various counties during the period in which weather records are available. Supplementary climatic notes for Alaska, the Hawaiian Islands, and the West Indies including Puerto Rico are listed.

Each topic of discussion throughout the book is well documented with references from the scientific literature, and is illustrated with a variety of well-chosen photographs, maps and line drawings. A complete index is appended.

THE BOOK OF TREES. *Second Edition, Revised.* *By Alfred Carl Hottes. A. T. De La Mare Company, New York.* $3.50. 7⅜ x 4⅞; viii + 440; 1942.

The Book of Trees is a new addition in the series of some 45 De La Mare Garden Books. As stated in the preface it "is intended for the amateur, the gardener and the nurseryman, but it makes no pretense of appealing to the foresters. The trees are discussed from the viewpoint of a horticulturist, not a botanist." Some 12 or more poems inserted in the text warrant the addition of the nursery-maid to the list of potential users. From a strictly scientific point of view the book offers little of value. The first 48 pages include brief discourses on such topics as "why plant trees?" and "the mystery of the autumn leaf." From the practical standpoint the book has much to recommend it. It contains helpful directions for selecting, planting, pruning, grafting, transplanting, propagation of, and generally caring for, trees. Several lists indicating rapidity of growth and suitability of trees for different purposes and localities are supplied. The main part, some 250 pages, consists of detailed descriptions of important deciduous and coniferous trees. Descriptions of characteristics, habitat, utilization, etc., are provided together with key for identification. There are numerous photographic reproductions of both the trees and their flowers. Many of these are excellent. Also included in the 200 or more illustrations are some pen drawings of plant parts and many sketches of characteristic features—fruits, twigs, buds, leaf sears, etc.

The final chapter is a table of some 270 deciduous and 85 coniferous trees, listing scientific and common names and characteristics as to height, shape, color of flowers, fruit and special remarks.

The book may be recommended to anyone who has an active interest in home gardens or city beautification —in fact, to anyone who "takes joy in supplying a fit environment for a growth that approaches perfection."

A BOOK OF ROSES. *By J. Ramsbottom. With Plates after the Originals in Redouté's "Roses". Penguin Books Ltd. Harmondsworth, Middlesex, England; New York.* 60 cents. 7¼ x 4⅝; 30 + 16 colored plates. 1941.

One of the most famous of the scientific treatises devoted to the description of species and varieties of the rose is *Les Roses* by Pierre-Joseph Redouté (1759–1849) who has been called "le Raphaël des fleurs." Successively engaged in the decorating of churches and castles, in painting the portraits of the most prominent persons in Luxembourg, and in floral decorative painting, Redouté was appointed, in 1822, "maitre de dessin pour les plantes" at the Jardin das Plantes in Paris. There he continued to add to the collection of paintings of plants begun by Gaston d'Orleans in the seventeenth century, and introduced the method of employing water-color on vellum instead of the gouache customary at that time. It is estimated that, in addition to his other paintings, he painted over a thousand roses. Many of these were included in the three editions of *Les Roses* that appeared during his lifetime. Sixteen of the water-colors there published are beautifully reproduced in this book. The plates are preceded by brief descriptions and data on the origin of the varieties depicted. An historical introduction contains, in addition to a brief biography of Redouté, interesting comments on the rose in literature, its use in religious ceremonies of different peoples and in heraldry, and notes on the distribution and origin of some of the most popular varieties. The format is attractive and the book makes a nice appearance on the drawing-room table.

SEEDING AND PLANTING IN THE PRACTICE OF FORESTRY. *A Manual for the Guidance of Forestry Students, Foresters, Nurserymen, Forest Owners, and Farmers. Third Edition.*

By the Late James W. Toumey and Clarence F. Korstian. John Wiley and Sons, New York; Chapman and Hall, London. $5.00. 9 x 5⅞; xxii + 520; 1942.

Among the more significant advances that have been made in silviculture during the decade that has elapsed since the appearance of the second edition of this book (cf. Q. R. B., Vol. 13, page 238 for mention of the second edition) are the construction of well-equipped extractories and seed-storage plants, the mechanization of most of the major operations in seed extraction, and the establishment of huge nurseries, some of which have a capacity of several million trees. The material on these has been revised and expanded to include the most up-to-date methods. The chapter on "Planting surveys and plans" has been enlarged in view of the recently increased emphasis in the programs of federal, state and private agencies on the production of nursery stock for planting on particular sites. Throughout the book a number of small-scale and generally outmoded methods and practices which have rather limited application in the United States have been included for the sake of completeness. As in the second edition, time scales, rather than cost figures, for the various operations are given, as the cost is dependent somewhat on wage scales which vary from time to time and according to locality.

Common and technical names of trees mentioned in the text are listed in an appendix, and author and subject indices have been provided.

WEEDS.

By Walter Conrad Muenscher. The Macmillan Company, New York. $4.50. 8½ x 5½; xxii + 579; 1942.

As in the three previous editions, the weeds (approximately 500 in number) described are indigenous to the northern United States and to Canada. The major portion of the book is a catalogue of the weeds, arranged in alphabetical order under their scientific names, by families. Each species or variety is described fully for purposes of ready identification. In addition information is included on its source and dissemination, type, geographic range, location and soil preferred, propagation, whether the weed is poisonous or harmful to stock, and specific directions for its eradication or control. The 123 illustrations show the whole plant and detail of root, seed, branch, flower and fruit of 320 varieties. There are four introductory chapters entitled, respectively, "The dissemination and importance of weeds," "Weeds of special habitats," "The control of weeds," and "Chemical weed control." These are followed by a key to the species, based primarily on flowers and fruits which the authors consider "more constant than the vegetative organs and habits of weeds." The fact that three editions of this book have appeared since it was first published six years ago is evidence of its popularity and usefulness. The revisions made for the present edition are not extensive.

STANDARDIZED PLANT NAMES. *Second Edition. A Revised and Enlarged Listing of Approved Scientific and Common Names of Plants and Plant Products in American Commerce or Use.*

Edited by Harlan P. Kelsey and William A. Dayton. J. Horace McFarland Company, Harrisburg, Penna. $10.50. 9 x 7⅜; xv + 675; 1942.

The first edition of this book, published in 1923, attempted to cover only the field of horticulture. The present edition has been prepared with other related interests in view, such as agronomy, farming, forestry, fruit-growing, gums and latex, pharmacy, spices and condiments, range and wildlife management and soil conservation. Approximately 90,000 separate entries of plant and plant product names appear—more than twice as many as in the first edition. Other innovations over the 1923 edition include: indications of pronunciation, the use of symbols to indicate clons, hybrids, polybrids, and plants useful to wildlife, and a glossary. The arrangement is alphabetical, in general by species, but includes also special plant lists such as drug plants, plants of significant economic use, poisonous plants, range plants, and state flowers and trees. The publication of this book will undoubtedly be most heartily welcomed by botanists, gardeners, nurserymen, pharmacists, librarians and editors.

FLORA ARTICA: BRYOPHYTA OF CANADIAN ARCTIC. *Collection of Father Artheme Dutilly.*

Identified and Annoted by William Campbell Steere. The Catholic University of America, Washington, D. C. 50 cents. 9¾ x 6¼; 1941.

This list of bryophytes forms a substantial contribution to our knowledge of Canadian flora. It represents painstaking and careful collecting and recording in many widely scattered regions in the Arctic. Father Dutilly, naturalist of the Arctic Oblate Missions, made the first collections in the summer of 1934 in the vicinity of Coppermine, Coronation Gulf and at Letty Harbour, Amundsen Gulf. Other summers he collected in the region west and north of Hudson Bay. The specimens were sent to various places for identification but by far the larger part have been identified by Steere and his co-workers. For each of the 163 forms there is a record not only of the collection number, date of collection, and local distribution but also of the distribution in larger,

natural geographical units, as follows: Labrador, Northernmost Quebec, West Side of Hudson Bay, Shore of Arctic Ocean, Melville Peninsula, Southampton Island, Baffin Island, North Devon Island, and Ellesmere Island.

TREES OF THE EASTERN UNITED STATES AND CANADA: *Their Woodcraft and Wildlife Uses.*

By William M. Harlow. Whittlesey House, McGraw-Hill Book Company, New York and London. $2.75. 7 x 4½; xiii + 288; 1942.

This pocket-sized book is designed for the hiker, camper, or anyone who is interested in knowing our eastern trees. Following the introduction which contains a non-technical discussion of the terminology and a general key, each important tree is described under the headings: Appearance, Leaves, Flowers, Fruit, Twigs, Bark, Habitat, Distribution, and Remarks. Other trees belonging to the same genus are briefly and clearly described so as to be easily distinguishable. The book is thoroughly illustrated with clear photographs of leaves, twigs, flowers, fruits, bark, etc., so that identification is made as simple and painless as possible.

This field book should be welcomed by those who would know the trees yet possess neither the technical knowledge nor the urge to ferret out the meaning of the terms used by the botanical fraternity.

DESERT WILD FLOWERS. *Revised Edition.*

By Edmund C. Jaeger. Stanford University Press, Stanford; Oxford University Press, London. $3.50. 8¼ x 5½; xxx + 322; 1941.

A key, prepared by Ruth Cooper, for the quick identification of desert plant specimens and a glossary are included in this edition (cf. Q. R. B., Vol. 15, p. 489 for notice of the first edition). With these exceptions and a few corrections in the text there are no differences between the two editions of this beautiful and fascinating laboratory manual. In all, 754 plants of the California deserts and related portions of Nevada are described and illustrated by excellent line drawings (executed by the author) or photographs. The paper selected for this book is suitable for filling in the coloring on the line drawings with indelible colored pencils—from living specimens it is hoped.

MORPHOLOGY

INTRODUCTION TO VERTEBRATE EMBRYOLOGY. *Fourth Edition.*

By Waldo Shumway. John Wiley and Sons, New York. Chapman and Hall, London. $4.00. 9 x 5¾; xi + 372; 1942.

Several sections of this edition have been altered or rewritten since the previous issue (noticed in Q. R. B., Vol. 11, p. 108) appeared. As before, the treatment is essentially comparative, with amphioxus, frog, chicks and man considered at comparable stages of early development. Organogeny is taken up by systems, with frog, chick, and human material treated separately. All sections are well illustrated, particular use being made of diagrammatic representations. With a view to making it more valuable to premedical students, the space devoted to human embryology has been considerably increased over previous editions. This addition has not lengthened the book as the sections dealing with laboratory material have been shortened. The chapters on the anatomy of vertebrate embryos in the third edition have been reduced to an atlas of illustrations of typical specimens and sections from the frog, chick, and 10 mm. pig, and the section on technique has been reduced to a single chapter.

The book contains one chapter which deals somewhat superficially with the problems of experimental embryology, but there appears to have been little effort to correlate this with the descriptive material presented.

Some sections of the book give rather thorough and up-to-date accounts of specific phases of development. However, one gets the impression, particularly in some sections on organogeny, that an effort has been made to present too many different things in too little space. This has frequently made it necessary merely to state that a structure appears at a certain time, rather than to give details of its formation. Specific references to similarities and differences which might be expected in a comparative work are limited for the same reason.

The book contains a glossary, index, and a limited bibliography (mostly of books) classified under several headings.

EMBRYOLOGY OF THE RHESUS MONKEY (MACACA MULATTA). *Collected papers from the Contributions to Embryology, published by the Carnegie Institution of Washington. Publication 538.*

Carnegie Institution of Washington, D. C. $1.00. 11½ x 9; 66 + 48 plates; 1941 (paper).

In the present volume the following five important papers on the placentation and early development of the Rhesus monkey are conveniently brought together and reissued for the use of investigators in the field of primate embryology: (1) First maturation division of the Macaque ovum, by Carl G. Hartman and George W. Corner; (2) Tubal ova of the Rhesus monkey, by Warren H. Lewis and Carl G. Hartman; (3) Development of the Macaque embryo, by Chester H. Heuser and George L. Streeter; (4) Fetal growth and develop-

ment of the Rhesus monkey, by Adolph H. Schultz; and (5) Placentation of the Macaque, by George B. Wislocki and George L. Streeter.

The first three are recent publications (see Q. R. B., Vol. 17, p. 181 for a review of these articles). The last two were published in 1937 and 1938 respectively (see Q. R. B., Vol. 14, p. 254 for a review of the Wislocki-Streeter paper). A full reference to each of the original articles is given in the table of contents.

During the years in which the attention of the Carnegie Embryological Laboratory has been devoted primarily to the development of the Rhesus monkey, tremendous progress has been made in the advancement of knowledge concerning early primate development. Their valuable Macaque collection represents an abundance of material of known conception age, collected and studied with superior facilities. While the use of the same material by different authors has resulted in some overlapping, it will be found that the papers supplement each other, and, taken as a whole, cover the principal developmental and growth phenomena that characterize this important animal.

TEXTBOOK OF EMBRYOLOGY. *Fourth Edition.*

By Harvey Ernest Jordan and James Ernest Kindred. D. Appleton-Century Company, New York and London. $6.75. 9⅝ x 6¼; xiv + 613; 1942.

The merited success of this useful and straightforward account of human development has resulted in a new, fourth edition.

While the present volume is constructed upon the same basis as its predecessors, the addition of important new descriptive material has made necessary a considerable amount of revision. Some chapters have been rearranged to give a more logical sequence and some of the earlier shorter chapters have been placed as sections, in small type, under the proper large chapters.

Perhaps the most valuable new feature is the addition of the more significant recent experimental and comparative data distributed among the respective chapters for the most part as separate terminal sections. This new material includes recent investigations on inductors, hormones, vitamins, parthenogenetic agents, *in vitro* development of mammalian embryos, and the results of various transplantation and extirpation experiments. References to the literature are placed as footnotes and collected in an alphabetically arranged bibliography at the end of the book.

The illustrations are well chosen and abundant. Many of the earlier figures have been eliminated and many new ones added.

ANATOMY OF THE NERVOUS SYSTEM: *A Textbook from the Developmental and Functional Point of View, and Atlas of the Nervous System of Man.*

By Olof Larsell. D. Appleton-Century Company, New York and London. $6.50. 9⅝ x 6¼; xviii + 443; 1942.

Although intended primarily as a medical text this book will prove a valuable addition to the general biological reference library. It presents not only a comprehensive account of the fine anatomy of the human nervous system but also a fairly complete consideration of its histogenesis and physiology. Each major division of the nervous system is treated in an individual chapter and brief summaries of illustrative lessons are given at the end of many of the chapters. Many excellent illustrations of sections and interpretive diagrams are included in the text and a special series of figures of sections of the central nervous system is arranged in atlas form at the end of the book. The book is authoritative, modern in outlook, logical in treatment, and extremely well written. There is a good bibliography and a full index.

MAMMALIAN STRUCTURE: *Atlas and Laboratory Manual of Cat Anatomy.*

By Charles J. Wideman, S. J. Loyola University Press, Chicago. $1.20. 11 x 9½; 60; 1941 (paper).

Designed for a one semester course in cat anatomy, this manual contains instructions for dissection and is illustrated with 34 original figures. The treatment is logical and the directions are easily followed. This reviewer feels, however, that there are several omissions which could hardly be justified in a course devoted exclusively to mammalian anatomy. The most serious of these is the lack of any mention of the autonomic nervous system. There is also no consideration of the external features of the body, the integumentary musculature is not mentioned, and the description of the body musculature is confined to the most superficial muscles of the lateral surface of the body, arm and leg. The last 19 pages of the manual are devoted to a full pronouncing glossary and an index.

PHYSIOLOGY AND PATHOLOGY

ANOXIA: *Its Effect on the Body.*

By Edward J. Van Liere. The University of Chicago Press, Chicago. $3.00. 9 x 6; xiii + 269; 1942.

This survey covers very thoroughly the work done on oxygen want, particularly the important developments within the last 25 years. The earliest studies on oxygen were reported by Lavoisier in 1777 in his paper "Experiments on the respiration of animals and the changes

which the air undergoes in passing through the lungs." It was not until nearly a century later (1875) that the French physiologist, Paul Bert, becoming interested in newspaper accounts of the effect of rarefied air on those who ascended to great heights in balloons, began the serious study of the effect of variations of barometric pressure on man. He persuaded three scientists to make an ascension for observational purposes. Although provided with oxygen, all three became too weak to make use of this. Two of the men died. The third became unconscious but lived, although, according to the instrument, the balloon reached a height of 28,200 feet. Since that time much work has been done on anoxia, especially since the greatly increased use of airplanes in recent times.

Four types of anoxia are recognized: (1) anoxemia, the most serious form, where there is lack of oxygen in the arterial blood. This type is characteristic at high altitudes, although it is produced by any condition which prohibits oxygen passing into the blood, such as in pneumonia, drowning, shallow respiratory movements, and embryological malformations of the heart or blood vessels; (2) anemic anoxia, where there is oxygen in the arterial blood but a shortage of functioning hemoglobin; (3) stagnant anoxia, where the arterial blood has a normal amount of oxygen but it is not given off to the tissues in sufficient quantities; (4) histotoxic anoxia, where the tissue cells are poisoned and unable to properly use the oxygen. All of these forms of anoxia have a profound effect on the body. Since they can be artificially induced it is possible to study them by the experimental method, either on man or animals. Following a discussion of these various laboratory procedures the author takes up the effect of anoxia on the various organs of the body: blood pressure, respiration, lymph, secretion of urine, metabolism, heat regulation, nutrition, water distribution in the body, and the nervous system. Of particular interest to the general reader at the present time are the chapters dealing with respiration, mountain sickness and high altitude sickness, acclimatization, and the nervous system.

Van Liere states that:

> . . . nervous tissue is the least capable of withstanding oxygen want. Whereas cartilage tissue, for example, may withstand total deprivation of oxygen for several hours without suffering any apparent deleterious effects, nervous tissue can withstand deprivation of oxygen for only a few minutes.

From the practical standpoint of the effect of anoxia on the special senses, the effect on the eye is doubtless the most important. There is evidence that there is a loss of accommodation and loss of visual acuity at altitudes at which pilots fly. There is also evidence that there may be some persistent aftereffects if the pilot has subjected himself to extreme altitudes. It is obvious that these aftereffects could well cause trouble in flying at lower levels and also in landing. Nearly all observers agree that the organ of hearing is the most resistant of all to anoxia, and, for practical purposes, it probably functions until psychomotor collapse occurs.

The volume contains tables and figures (17) in the text, each section is thoroughly documented and an excellent working index is provided.

HIPPOCRATIC MEDICINE: *Its Spirit and Method.* *By William Arthur Heidel. Columbia University Press, New York.* $2.00. 8 x 5¼; xv + 149; 1941.

Concerning Hippocrates very little is known with certainty. Although his contemporaries are agreed that, unlike Socrates, he did commit his theories and teachings to writing, there are no existing documents that can be considered accurate copies of what he may have written. Yet there is a great body of anonymous medical treatises dating from the age of Hippocrates and later times, some of which undoubtedly embody his beliefs, but there is so much inconsistency among them that it is hardly possible to put one's finger on any specific statement and say "This is authentic" or to say of another "This is an interpolation."

But if we broaden the term "Hippocratic medicine" to make it include all the body of medical belief that had accrued in Greece during the fifth and fourth centuries B.C. and make this the subject of inquiry, the fact stands out that at this time medical thought was divided up into rival schools of conflicting opinion just as it is today. Conspicuous among these was that at Cos to which Hippocrates himself belonged, and the rival school of Cnidos. But it is not known what specific medical theories characterized these schools. For instance, in one ancient document we find quoted the commonplace proverb, "One man's meat is another man's poison," while in another it is naively stated that every symptom has its own specific remedy with which it should invariably be treated, and since all the remedies are known it is impossible that any advance in medical theory can ever take place. There was also much argument as to whether medicine was an art, a science, or a philosophy. Whatever Hippocrates may have thought about what medicine was, there is no doubt at all as to what he thought it ought to be. The entire object of his writings was to make medicine scientific.

It was for this reason that Hippocrates has been called the "Father of Medicine." He was not the first physician in history—far from it. The first Greek philosopher of whom we have any record, Anaximander, was also a physician, and there is evidence in the Homeric epics of medical activity in those days. But Hippocrates was the first to attempt to put medicine on a strictly scientific basis, and to appreciate what this involved we must know something about Greek sci-

entific method. A whole chapter is devoted to this subject.

It was Heidel's intention to write a series of books, covering all phases of Greek science, of which the present work was to be one. But unfortunately death intervened just after the first volume was completed. While we cannot but regret that the author was not spared to complete his labors we can at least be grateful that this one treatise has appeared.

The index covers nine pages and appears to be quite detailed.

IMMUNOLOGY. *Second Edition.*

By Noble Pierce Sherwood. C. V. Mosby Company, St. Louis. $6.50. 9 x 5⅞; 639; 1941.

The author indicates in the preface that this book is primarily written for medical students. It seems well adapted for this purpose especially during the present national emergency when the medical curriculum is accelerated and the conservation of time is so important. The author has refrained from entering into lengthy discussions of debatable points, but has presented the existing opinions of the authorities in clear, concise statements. Due to the many subdivisions of the chapters and the frequent definitions of terms, the reading of the subject matter is not always smooth. In fact one may occasionally feel as though he is reading a dictionary or a pocket encyclopedia. However, these properties together with a style of writing that is easily understood make the book a good text for its designed purpose.

The theoretical background of immunological reactions is presented in such a manner that the student will be better able to evaluate properly the significance of diagnostic tests as performed in the laboratory. Many of the diagnostic tests in widespread use are described in sufficient detail to be understood, but not adequately enough to serve as a laboratory guide. References are given at the end of the chapters for those who wish to consult the original literature or desire full descriptions of the laboratory technique.

Two worthwhile chapters have been added to the second edition of this book, one on the reticulo-endothelial system and the other on serum reactions. For those not acquainted with colloidal chemistry an elementary discussion of the subject is presented in the appendix. Many black and white figures and several colored plates illustrate the text. Author and subject indexes are included.

NEURAL MECHANISMS IN POLIOMYELITIS.

By Howard A. Howe and David Bodian. The Commonwealth Fund, New York; Oxford University Press, London. $3.00. 10 × 6⅔; vii + 234; 1942.

At the present time, investigators in the field of poliomyelitis are not so pessimistic as they were a few years ago. Indeed, there is an optimism in the group that presages intensive and fruitful work in the near future. However, one is struck by the lack of investigators in this field who have had fundamental training in neuroanatomy or neurology. Progress is being made, however, and already there are some neurobiologists who have been making significant contributions to the subject of poliomyelitis, as is evidenced by the present book. This excellent monograph, in which are recorded the investigations of two workers, embodies a series of experiments, many of them already published, which grew out of the problem concerning the rôle which nerve fibers and nerve cells play in the penetration into and migration of the virus within the body. In presenting this material, the authors have attempted not only to achieve a broad and unified basis for further investigations of virus-neuron relations in general, but also to include some of the possibilities which such a study offers for understanding both the behavior of the virus and the biological processes in the nervous system. Material presented includes: the mechanism and rate of virus spread in peripheral nerve, the genesis of cerebral lesions, the rôle of neurons in the dissemination of virus in the central nervous system, the behavior of virus in peripheral nerves and in non-nervous tissues, the portal of entry problem in man and in experimental animals, the pathology of early arrested and non-paralytic poliomyelitis, virus-refractory states in nerve cells, and problems of immunity in poliomyelitis presented by second attacks. The book is effectively illustrated with microphotographs, charts and tabular material and is provided with an extensive bibliography and a complete index.

ENCEPHALITIS. *A Clinical Study.*

By Josephine B. Neal and Collaborators. Grune and Stratton, New York. $6.75. 9 x 6; xviii + 564; 1942.

This book adequately fulfills a long-felt demand of the medical profession for an easily available source of information pertaining to the various encephalitides and to the clinical treatment of these dread maladies. Josephine Neal and her equally qualified collaborators have done a remarkable job of organizing and presenting the present knowledge of these diseases, of which a great amount must be accredited to them and their exhaustive research program.

The first chapter, by Neal, deals with a general discussion of encephalitis regarding the etiologic agents involved, viral and otherwise, and the great difficulty of making differential diagnoses clinically. R. S. Muckinfuss presents in the second chapter an excellent report on the epidemiology of epidemic encephalitis. The following headings of the remaining chapters indicate the

character and scope of the book: Neurological complications following acute infections and vaccination; The clinical course of epidemic encephalitis; The treatment of epidemic encephalitis; The surgical treatment of post-encephalitis; Post-encephalitic behavior disorders in childhood; The pathology of encephalitis.

The chapters on the clinical course of epidemic encephalitis and pathology of encephalitis are particularly well integrated and complete with case histories and necropsy reports. The chapter on the treatment of epidemic encephalitis is interesting and instructive. Vaccines, such as herpes vaccines, and drugs, such as bellabulgara, that show promise therapeutically are discussed.

Each chapter has an extensive bibliography. The book has an adequate subject index as well as a useful index of proper names.

FOUR TREATISES OF THEOPHRASTUS VON HOHENHEIM CALLED PARACELSUS.

Edited, with a Preface by Henry E. Sigerist. Translated from the Original German, with Introductory Essays by C. Lilian Temkin, George Rosen, Gregory Zilboorg and Henry Sigerist. The Johns Hopkins Press, Baltimore. $3.00. 9 x 6; xii + 256; 1941.

Published in commemoration of the four hundredth anniversary of the death of Paracelsus, this book presents translations of four of his treatises, chosen to illustrate four different aspects of his work. The first treatise, the *Sieben Defensiones*, is Paracelsus' own justification of his ideas and methods; the second, an essay on the diseases of miners, is the first monograph ever written on the diseases of an occupational group; the third, concerning mental diseases, is a pioneering work in psychiatry; the fourth, a treatise on nymphs, sylphs, pygmies, salamanders and other spirits, is included as a sample of the philosophy and theology of Paracelsus.

The importance of Paracelsus in the history of medicine has long been a controversial point among historians. His erratic ways and his violent tirades against contemporary physicians gave rise to much bitter criticism of him and his methods, which could not fail to influence the opinions of later writers. A first-hand evaluation of Paracelsus' thoughts through study of his works has been impossible for the average reader because his books were all written in the 16th century German of Switzerland, a language which offers peculiar difficulties to the translator. The present translations, together with the brief but illuminating introductory essays which accompany them, give the reader a basis for forming a real considered judgment concerning the place of this almost legendary figure in the development of science. We predict that an increased recognition of the originality and sincerity of the man and a lessening of emphasis on the "bombastic" phase of his character, will result.

A MANUAL OF ENDOCRINE THERAPY.

By Bernard L. Cinberg. Chemical Publishing Company, Brooklyn. $3.25. 8½ x 5½; v + 178; 1942.

The field of endocrinology has expanded so rapidly during the past decade that the general practitioner cannot even hope to keep abreast of the subject. Even if he had time to read all the literature, there would still remain for him the colossal task of critically analyzing and evaluating the various new therapeutic agents, procedures and practices in order to decide what is practical and what is impractical in meeting his own clinical problems.

In this little book, Cinberg has attempted to bring together the pertinent aspects of modern endocrinology and arrive at a safe and sane plan of endocrine therapy for the general practitioner. The result is not a text-book, hence it presents the subject without the details, the controversies and the lengthy bibliographies that burden modern endocrinology literature. The discussions are centered around a number of commercial endocrine products, and are concerned with their therapeutic value in treating human maladies. Where observations on the human have not confirmed the findings on certain lower mammals, the author states the facts quite frankly, and warns against the dangers patent in the assumption that what will work with a rat will work with a human.

The short section on diagnostic procedures in endocrine malfunction designed for the unassisted practitioner, and the list of therapeutic suggestions for treating a variety of maladies relating to the endocrines, contribute alike to the excellence and usefulness of this volume in the hands of the hurried and harried physician.

LABORATORY DIAGNOSIS OF PROTOZOAN DISEASES.

By Charles Franklin Craig. Lea and Febiger, Philadelphia. $4.50. 9¼ x 5¾; 349 + 4 plates; 1942.

This excellent book is intended as a guide to diagnosis of protozoan diseases particularly for the less expert physician and laboratory technician. As such it serves its purpose admirably. The sections on each disease contain detailed descriptions of the morphology of the parasite, methods of collection and microscopic examination, methods of culture, serological tests for the presence of the parasite, and a general critique of the various diagnostic procedures. The different methods are described in great detail, and the precautions necessary for their successful use are pointed out. The diagnostic worth of each method is critically evaluated,

in many cases on the basis of the author's own experience. Of particular value are the suggestions made as to diagnostic procedures to be used by laboratories of limited facilities. The book is well and amply illustrated with drawings and photographs of all the organisms mentioned. Considerable care was used to show the various forms which each organism may take.

The book is divided into six parts. The first deals with amebiasis and flagellate infections; the second with the leishmaniases; the third with the trypanosomiases; the fourth with coccidiosis; the fifth with the malaria plasmodia; and the last with balantidiasis. There is an extensive list of references and both an author and a subject index.

BAINBRIDGE AND MENZIES' ESSENTIALS OF PHYSIOLOGY. *Ninth Edition.*

Edited and Revised by H. Hartridge. Longmans, Green and Company, New York and London. $5.00. 8⅓ x 5½; x + 687; 1941.

The original purpose of this book (cf. Q. R. B., Vol. V, p. 253 for mention of an earlier edition) was to provide, in concise form, the fundamental facts and principles of physiology and thus to serve as an aid to medical students preparing for examinations in physiology. The book well accomplishes this purpose inasmuch as it contains the essentials of mammalian physiology.

In the eighth edition, many chapters were rewritten and the whole book was brought up-to-date. As a consequence there was no complete rewriting of chapters for the ninth edition. In many cases, however, new material has been substituted for the old in such a way as to retain the size of the book as a whole. Although relatively complete on such subjects as the circulatory system, muscle and nerve physiology, the book is not detailed in its treatment of metabolism, vitamins, etc. While no bibliography is included this is hardly essential considering the purpose for which the book is designed. The excellently prepared index will be found most useful to students.

ALIMENTACION Y NUTRICION EN COLOMBIA

By Jorge Bejarano. Editorial Cromos, Bogotá. 8 x 5½; 166; 1941 (paper).

The author, professor of hygiene at the University of Bogotá and president of the Red Cross of Colombia, from the evidence presented in this book appears to be greatly distressed over the lack of good judgment in the choice of foods by a large percentage of the population of his country. He finds that they use too much sugar and starchy food and too little meat, milk, eggs, fruits and vegetables. Likewise the consumption of locally-made alcoholic drinks is excessive. He states, however, that in most places water supplies are poorly guarded and sometimes become contaminated with fecal material. Under these circumstances especially we should be inclined to agree with the natives that water is indeed unfit to drink and alcohol a beverage to be preferred. The book contains a good account of the recent advances in the science of nutrition. It should be of interest and profit to physicians, public health workers, and intelligent laymen in Colombia and among other Spanish-speaking populations.

BIOCHEMISTRY

BIOLOGICAL SYMPOSIA, *Volume V. I. Comparative Biochemistry. II. Intermediate Metabolism of Fats. III. Carbohydrate Metabolism. IV. Biochemistry of Choline.*

Series Edited by Jaques Cattell. Volume V Edited by Howard B. Lewis. Jaques Cattell Press, Lancaster, Pennsylvania. $3.00. 9¾ x 6¾; ix + 247; 1941.

This fifth number of the series published by the Jaques Cattell Press is the second dealing with current biochemical problems. This volume is composed of the four symposia arranged by the Council of the American Society of Biological Chemists for the Chicago meeting of the Federation of American Societies for Experimental Biology in April, 1941. The first section consists of papers on End products of nitrogen metabolism in plants and animals, by H. B. Vickey and H. B. Lewis, and on The merging of growth factors and vitamins, by W. H. Peterson. These papers, presented with the purpose of directing the interests of some of the young students of biology to the significance and importance of the study of comparative biochemistry, make profitable reading and should go far toward accomplishing their end.

Aspects of the intermediary metabolism of fats are treated by H. E. Carter, S. Soskin and R. Levene, R. G. Sinclair, and H. E. Longnecker. In the symposium on Carbohydrate metabolism, problems of oxidation, phosphorylation, etc. are discussed by T. R. Hogness, C. F. Cori, O. Meyerhof, and E. A. Evers, Jr. These two sets of articles emphasize the close interrelationships existing between fats and carbohydrates in their utilization by the organism. Both stress the importance of phosphoric acid as an intermediary agent in both fat and carbohydrate metabolism. Oxidation of fatty acids is presented in direct relationship to that of carbohydrates.

In the fourth section, The biochemistry of choline, E. W. McHenry, W. H. Griffith and D. Glick respectively consider the relations of choline to fat metabolism, to pathological changes in the liver and kidneys and to functions of the nervous system. The rôle of choline in the important process of transmethylation and its relation to methionine and creatine formation

are ably discussed by V. du Vigneaud in the concluding paper.

Because this volume deals with some of the newest and most revolutionary aspects of modern biochemistry, it must perforce make fascinating reading to most biologists. One might class these papers as progress reports. In most instances the authors have presented the facts of the subject in a logical and interesting manner and with a minimum of theorizing beyond the data. To some this will indeed be refreshing; unfortunately it is not always a characteristic of general review papers. The volume should find a wide audience not only among biochemists, but also among biologists in general.

THIS CHEMICAL AGE: *The Miracle of Man-Made Materials.*

By Williams Haynes. Alfred A. Knopf, New York. $3.50. 8⅜ x 5⅝; vii + 385 + xxii. 1942.

Discoveries made since World War I by American workers in the field of synthetic chemistry have been numerous and almost miraculous. The author's purpose in writing this book is to give, in non-technical language, a clear picture of the origin and growth of our great modern chemical industry and to bring out the effect which it has had in the life of each one of us.

The first two chapters are devoted to an explanation of the few basic chemical facts necessary to an understanding of what is to follow. Then, in order, are discussed coal tar dyes, perfumes, pharmaceuticals, sulfa drugs, rubber, textiles, plastics, and munitions. The author shows how World War I, by cutting off our supply of synthetic chemicals from Germany, was of prime importance in making the present day American chemical industry foremost in discovering and producing synthetics in the world. Emphasis is placed on the fact that man-made copies of natural products are not mere substitutes but are usually superior to the natural products.

The book is, in general, well written and is easy to read. There are a few technical errors which might be ascribed to the proofreader. The book will not interest the trained chemist. However, it should appeal to the general reader and hence it fulfils its purpose.

A brief annotated list of additional titles of a general chemical nature, a glossary of terms, and a very good index are included.

SYNOPSIS OF APPLIED PATHOLOGICAL CHEMISTRY.

By Jerome E. Andes and A. G. Eaton. C. V. Mosby Company, St. Louis. $4.00. 7⅞ x 4⅞; 428; 1941.

Although this book was written as a text, the authors point out in the preface that "in some ways the book may be regarded more as a handbook than as a text." This is undoubtedly true as most of the book is primarily a catalogue of short statements of chemical changes accompanying various physiological and pathological conditions, and equally short statements of testing methods.

By far the largest part of the book is devoted to the blood, with shorter sections on the cerebrospinal fluid, urine, functional tests, gastric analysis, and basal metabolism. Most of the tests commonly applied are given, and references to tests for constituents not discussed are given in several places. There is no discussion of tissue analysis. The laboratory methods are not extensively discussed from a biochemical standpoint, but the "cook-book" directions and the provision of formulae for calculating quantitative results should appeal to those who have only occasional recourse to biochemical tests. References are given for many, but not all of the tests. There is a complete index and an appendix with instructions for the preparation of reagents and standard solutions.

This volume is primarily for the physician and medical student rather than for the biochemist, and should prove a valuable book in its field.

VITAMINS AND MINERALS FOR EVERYONE.

By Alida Frances Pattee. Hazel E. Munsell, Technical Advisor. G. P. Putnam's Sons, New York. $2.00. 8 x 5⅜; xviii + 242; 1942.

In this book the latest findings on vitamins and minerals are rather interestingly arranged for quick reference. The material has been extremely simplified so that no specialized knowledge is required to understand it. At a glance one is told what the various vitamins and minerals are, what they do for the body, what foods contain them, and how much of these foods one needs daily.

One valuable and useful feature is the presentation of Food Tables from which the vitamin and mineral adequacy of a diet can be determined without the usual calculations. These tables show how much of each vitamin and mineral may be obtained from average servings of many of the most common foods. Other tables show foods in the order of their descending potency from those containing most to those containing least of these substances.

Vitamin concentrates are discussed, and sample menus are suggested which furnish a day's quota of vitamins, minerals, and calories for a sedentary adult.

SEX

OUR SEX LIFE. *A Guide and Counsellor for Everyone. Second Edition, Revised.*

By Fritz Kahn. Translated from the German by George Rosen. Alfred A. Knopf, New York. $5.75. 9⅜ x 6¼; xxxv + 459 + 41 plates; 1942.

This second edition of *Our Sex Life* (cf. Q. R. B.: 1939, 3, p. 377 for notice of the earlier edition) is not significantly different from the first. Kahn presents a thorough and interestingly written discussion of most phases of sex anatomy, sex hygiene, sex behavior, and the numerous sex problems facing the individual. "Although the author at times waxes a little too poetic, the book contains more sense and fundamental information than many of the *vade mecums* of the sex life now on the market." It is to be noted that the book still contains a striking contradiction to the later experimental work: "There are no 'safe' days during the woman's monthly cycle." The "numerous theories concerning allegedly 'safe' periods . . . are pure creations of fantasy."

As a whole, however, this translation of *Unser Geschlechtsleben* is excellent and deserves a high rank among books of its type.

BIOMETRY

PHYSICAL MEASUREMENT OF YOUNG CHILDREN: *A Study of Anthropometric Reliabilities for Children Three to Six Years of Age. University of Iowa Studies. Studies in Child Welfare. Volume XVIII, Number 3. Serial Number 394.*

By Virginia Bergstresser Knott. University of Iowa Press, Iowa City, Iowa. $1.35 (cloth); $1.00 (paper). 9⅛ x 5¾; 99; 1941.

Variation in physical measurements resulting from differences in technique is a constant challenge to the anthropometrist who strives for some measure of reliability in his work. The present study was undertaken for the primary purpose of evaluating the differences arising from three different sources, namely: (1) those resulting from observations by two different technicians; (2) those arising from successive observations of the same measurement by a single technician; and (3) those arising from the observations of a single technician on a subject being measured from several positions. A secondary aim of the study was that of determining the most reliable methods for measuring preschool children.

Thirty-five different physical measurements on some 131 different children ranging in age from 3 to 6 years make up the data herein presented. In general, it was found that successive independent observations by a single technician showed less variability than those between two different technicians. No marked differences were found in reliability of measurements taken with the subject in two different positions. For a complete record of growth in pre-school children, the author recommends that stature be measured at least 10 times a year; length of extremities and body girths, 3 or 4 times a year; and extremity girths and head measurements about once or twice a year.

The report includes a critical evaluation of 44 papers on anthropometry, and a number of tables, graphs and photographs.

STATISTICAL METHODS APPLIED TO AGRICULTURAL ECONOMICS.

By Frank A. Pearson and Kenneth R. Bennett. John Wiley and Sons, New York; Chapman and Hall, London. $4.00. 9 x 5⅞; vii + 443; 1942.

This book was written primarily for those interested in the application of statistical methods to agricultural economics. The illustrations are largely drawn from the fields of farm management, marketing, and prices. However, these illustrations are similar to those which might have been taken from other fields in agricultural economics and business, so that the usefulness of the book to the general statistician is thereby much enhanced. The volume is designed for use as a textbook in colleges and universities, or as a general reference book for statistical workers. The arrangement follows the usual procedure: measures of central tendency, variation, association and reliability. The book differs from most textbooks in that it contains two chapters on the tabular analysis of relationships—a subject ignored in many texts. In the chapters on testing reliability, emphasis is placed on problems which arise in the social sciences. The appendix contains: A Glossary of symbols used in the book, A method of calculating sums of squares and sums of products with tabulating equipment, The Doolittle method of solving normal equations for net regression coefficients, and other general tabular information. References are given as footnotes in each chapter. An index has been provided. This volume makes a significant contribution to literature in the statistical field, and should serve as a useful tool for research workers, students and teachers alike.

THE BULLETIN OF MATHEMATICAL BIOPHYSICS. *Volume 4, Number 3, September, 1942.*

Edited by N. Rashevsky. University of Chicago Press, Chicago.

This number contains the following papers: A mathematical theory of protoplasmic protrusions: I., by Henry E. Stanton; A theory of electrical polarity in cells: II, by Robert R. Williamson; Green's functions in biological potential problems, by Alvin M. Weinberg; Further contributions to the mathematical biophysics

of visual aesthetics, by N. Rashevsky; Some observations on the simple neuron circuit, by Walter Pitts; Delayed absorption and diffusion in colloidal media, by Herman Branson; An expression for the rate of return of an egg after artificial deformation, by H. D. Landahl.

PSYCHOLOGY AND BEHAVIOR

FOUNDATIONS FOR A SCIENCE OF PERSONALITY.

By Andras Angyal. The Commonwealth Fund, New York. $2.25. 8¼ x 5¼; xii + 398; 1942.

In this book the author has attempted to outline a general theoretical basis for a "science of personality," holistically conceived. He starts with the premise that such a basic theory must fulfill three conditions. First, it would require more specific and positive formulations with regard to the nature, organization and laws of personality, than are at present available. Under this heading the general pattern of life processes is considered in its dual nature—the tendency toward increased autonomy (self-determination, mastery of environment, aggression or regression) and the tendency toward homogamy (the trend of the individual to conform with the superindividual wholes of society, culture, etc.). The second desideratum would be the formulation of a method of synthesis of segmental data whereby the facts of anthropology, psychology, physiology, biology and other "segmental sciences" would be related not with each other but rather to the "psychophysically neutral processes" of the total organisms. In this connection the author elaborates a theory of "systems" which may be summarized as follows: "Parts are characterized by being relatively complete in themselves and by occupying a position directly in a system. The concept of part should be restricted to mean 'immediate' part. System action spreads in a continuous manner upward or downward over the entire whole or it may be limited to a certain region." The third condition is stated as the development of a new set of concepts of terms, in general more dynamic than those employed in the "segmental" sciences. However, the author suggests very few new ones but does assign new meanings to a number of current and generally accepted terms.

The greater part of the book was presented in a series of lectures at the Henry Phipps Psychiatric Clinic of the Johns Hopkins University. Its interest is not restricted, however, either in its general import or in the specific problems of illustrations advanced, to the psychiatric field. It is a stimulating, well-written book, offering an interpretative background for empirical findings that should be of interest to anthropologists, biologists, physiologists, psychologists and others.

A LONG-TERM STUDY OF THE EXPERIMENTAL NEUROSIS IN THE SHEEP AND DOG *with Nine Case Histories. Psychosomatic Medicine Monographs, Volume II, Nos. III and IV, 1941.*

By O. D. Anderson and Richard Parmenter. National Research Council, Washington, D. C. $3.50. 10 x 6¾; vii + 147; 1941.

In this report of a long-term investigation of neurosis in the sheep and dog, carried on at the Cornell University Behavior Farm, in Ithaca, N. Y., the authors have presented in detail their methods of procedure and their observations. Their approach is that of the conditioned reflex method. Their primary interest is in the causative factors at the basis of the neurotic disorders induced. The second chapter is devoted to a detailed description of the manifestations of experimental neurosis, and the wide variation in symptomatology is stressed. In the third chapter, procedures which precipitate and maintain the neuroses are described. Particularly interesting are the comments on the influence of the examiner on the experimental animals' reactions.

A discussion of the experimental findings is presented in the fourth chapter. As a working hypothesis, the authors state: "Repeated and prolonged emotions, incident to the experimental procedure, produce a chronic imbalance of the internal secretions which induce a constant state of imbalance of the chemistry of the nerve cells. A change in the irritability of the nervous system results. The nervous system may become hyperirritable." The authors feel that by laying a groundwork of physiological findings they will have a basis for later more extensive psychological investigations of neurosis.

In the Appendix, a case history of each experimental animal is presented. There is a bibliography of 24 titles.

THE MEASUREMENT OF ADULT INTELLIGENCE. *Second Edition.*

By David Wechsler. Williams and Wilkins Company, Baltimore. $3.50. 9 x 6; xi + 248; 1941.

This second edition of Wechsler's book (first edition noticed in Q. R. B. Vol. 15, p. 117) follows closely the first edition. The development and use of the Wechsler-Bellevue Scales are described in detail. The material is presented in three parts. Part I is devoted to an excellent discussion of the nature and classification of intelligence. In Part II, the Bellevue Scales are considered in detail. In the present edition, a new chapter, Diagnostic and clinical features, is included. Part III consists of the manual of instructions in the criteria for scoring the various tests. There are five short appendices of special statistical methods used. A final section is devoted to intelligence quotient tables. There is an index.

YOUR PERSONALITY: *Introvert or Extrovert?*
By Virginia Case. The Macmillan Company, New York. $2.50. 8⅜ x 5¼; viii + 277; 1941.

This book which is written in popular style and for popular consumption, presents the concepts of the Swiss psychiatrist Carl Gustav Jung, encompassed by the terms "introvert" and "extrovert," in relation to types of temperament. The manuscript was read by Jung and approved by him for publication. The author offers no original ideas of her own, but her presentation of Jung's concepts seems accurate and clear. The book has little technical interest, but is readable and will no doubt find its public among those whose reading is motivated by a desire for self-understanding and self-help.

PHYSIOLOGICAL PSYCHOLOGY.
By S. R. Hathaway. D. Appleton-Century Company, New York. $2.75. 8 x 5⅜; xxi + 335; 1942.

This book is designed as a text to acquaint the psychologist with basic facts relating to the anatomy and physiology of the human nervous system. The subject matter, in the main, is descriptive and presents a concise summary of current knowledge of the structure and function of nervous tissue. There is little of actual "psychology" included, and the viewpoint is essentially mechanistic. There is a selected bibliography and an index.

DE OMNIBUS REBUS ET QUIBUSDEM ALIIS

A SHORT HISTORY OF SCIENCE *to the Nineteenth Century.*
By Charles Singer. Clarendon Press, Oxford; Oxford University Press, New York. $3.75. 8½ x 5⅝; xiv + 399; 1941.

Doctor Singer begins his interesting history with the definition of science. This he conceives to be "no static body of knowledge but rather *an active process* that can be followed through the ages." Science was an active process when early man was learning and improving methods of producing fire. The beautifully drawn cave pictures of the bison with arrows embedded in the heart (a pictorial study of the method of killing) are evidences of accurate observation and a knowledge of anatomy by prehistoric man. In the agricultural stage, man developed a system for determining the onset of the season which led to a calendar. With commerce, the system of numerical notation evolved. Of the "great primary discoveries which made social life possible" nothing is known. Nevertheless the people who made these discoveries were taking part in the development of science. They were doing the spade-work which made it possible for later civilizations to produce men "who were conscious of science as a distinct process and who were conscious, too, that the process might be indefinitely extended. . . ." While the present work begins with the earliest known records that are in any degree complete, the author believes that ultimately a work will be written that will include many of the sources of scientific development of the ancient world. "The ancient world presents us numerous such instances fathered by necessity and mothered by experience. All have a like claim to be included in a history of science."

Throughout his book Singer links the progress of science with the lives of the great men in science—covering a period of about 2500 years. The first period he terms "The Rise of Mental Coherence" (600–400) and begins with the Ionian Greek Thales (629–565 B.C.). Such men as Anaximander, Hecataeus, Heracleitus, Democritus, Herodotus, Pythagoras, and Hippocrates belong in this period which culminates in the great intellectual revolution associated with Socrates (470–399). "Out of the conflict between the Socratics and the physical philosophers arose the main streams of later Greek thought. These two streams derive their titles and their tendencies from the two gigantic figures that occupy the stage during the fourth century, the age of Plato and Aristotle."

The second period (400–300) Singer terms "The Great Adventure" and here he discusses the several "unitary systems of thought" of the Platonian and Aristotelian schools. Singer has so admirably summed up in the final paragraph of this chapter the contents of the next three chapters that we quote in full, not only to give the reader a comprehension of the ground covered but an example of the author's lucid style.

In leaving the heroic age of Greek science we would again emphasize the "universal" character of the philosophical attempt that we call the "Great Adventure." The scientific activity of the age partook of the nature of what we should now term "philosophy." The object of each investigator was to fit his observations and the laws that he deduced into some general scheme of the universe. From their day to ours philosophy has continued her attempt thus to storm the bastions of heaven. But with the new age that we have to discuss, there was a failure of nerve in that great frontal attack. Science, becoming gradually alienated from philosophy, begins to proceed by her own peculiar method of limited objectives. The first series of these attempts resulted in the "Great Failure," the story of which we shall trace through two thousand years (Chs. III, IV, V). Nerve fails first, as with the Alexandrian school (Ch. III), next Inspiration falters under the Roman Empire (Ch. IV), lastly Knowledge itself fades in the Middle Ages (Ch. V). At length there is a rebirth. The science of the Renaissance—in which we still live—began again to proceed by the method of limited objectives (Ch. V). How that method differed from that with which the Great Failure is associated is a matter which we shall have to discuss.

The period 1250–1600, "The Revival of Learning," was marked by the rise of humanism, the introduction of the art of printing and the revival of the natural

sciences. It was an age of great accomplishment but the sciences were dominated by the models of antiquity. "The Insurgent Century" (1600–1700) brought the downfall of Aristotle and new attempts at synthesis. Credit belongs to Galileo more than to any other man for the break with ancient modes of thought and the opening up of new lines for scientific progress which led to The Mechanical World of the XVIII and XIX centuries, a period marked by the "Enrollment of Determinism." It is the era of Newton, Faraday, Kant, Linnaeus, Darwin, and many others who have had a profound influence on our own times.

Singer brings out very clearly that the path of scientific progress has by no means been a straight-forward line yet one finishes the book with the feeling that in the background, throughout the ages, there have been certain tendencies leading to the attained end. Many excellent drawings are included in the text. The index is confined to the names of the individuals occurring in the history.

COLLEGE AND UNIVERSITY MUSEUMS: *A Message for College and University Presidents.*

By Laurence Vail Coleman. American Association of Museums, Washington, D. C. $1.25. 9 x 6; viii + 73; 1942.

The author of this work believes that every institution of learning should have not only one museum but several museums, the reason being that objects suitable for museum display are less related to each other than to the departments in which they are studied. The United States National Museum in Washington (which the author does not discuss because it is not a university museum) is an excellent example of what a university museum should not be, for here collections dealing with art, science and history are all assembled under the same roof. The student who goes to Washington for advanced research is not likely to be disturbed by the presence of objects in which he is not interested displayed in other halls of the same building, but the college student who is generally a beginner and who is also likely to be already inconvenienced by having to get his bibliographical material from a building that may occupy a position on the campus remote from the laboratory and the class room, will be even further handicapped if the material which he wishes to examine is kept in a locality different from these.

Furthermore, there are fundamental differences among the three types of museums. The historical museum is likely to be congested with objects of no particular interest donated by well meaning patrons who wish to get rid of them, and these the college must accept, to avoid risk of offending those on whom it may depend for pecuniary support. (The reviewer has in mind a well-known institution of higher learning which had to accept from the bereaved heirs of its founder a wax model of the bacon and eggs which he left on his breakfast plate just before meeting a violent death. Such objects should of course be segregated in a room where the donor may inspect them but where students are not required to go.)

The exhibits in the art museum are for obvious reasons likely to be loans. Since these circulate through many museums it follows that in the long run the exhibits in different museums are likely to be very much the same. On the other hand, the exhibits in the museum of science are likely to be the property of the college, and if these exhibits illustrate what the Germans call *Heimatskunde* as they should, every college museum is likely to have its own personality, distinct from all the others.

The administration of such a museum presents problems quite different from those which arise in the case of the art museum and constitute another reason why the two kinds of museums should not be consolidated in the same building.

On the other hand, if each department has its own museum, there arises another danger to be guarded against. Museum supervision requires a highly specialized training. To build up a college collection, to index and classify new acquisitions, to keep the documentary records correctly filed, and above all to see that borrowed material is returned promptly to its correct place when due is no mean task, and requires the full time of a skilled curator. It is beyond the ability of the ordinary professor or his assistant.

The author discusses the various problems that arise in museum management and illustrates the way these have been met successfully at some of the best known universities by photographs and floor plans. He might have made his thesis more convincing by including some horrible examples of mismanagement by way of contrast, but it is not difficult to imagine why this was not done.

The author's object in writing the book is indicated by the subtitle. It would be a fine thing if every college president in the country would familiarize himself with the contents of this book.

SCIENTISTS FACE THE WORLD OF 1942: *Essays.*

By Karl T. Compton, Robert W. Trullinger and Vannevar Bush. Rutgers University Press, New Brunswick, N. J. $1.25. 9 x 6; [80]; 1942.

THE UNIVERSITY AND THE FUTURE OF AMERICA.

Contributing Authors: Isaiah Bowman, Walter Bradford Cannon, Edwin Francis Gay, Herbert Hoover, Edwin Powell Hubble, Herbert Spencer Jennings, Charles Franklin Kettering, Ernest Orlando Lawrence, Archibald MacLeish, Robert Andrews Millikan, Lewis Mumford, William Fielding Ogburn, Roscoe Pound,

Aurelia Henry Reinhardt, Edward Lee Thorndike, and Ray Lyman Wilbur. Stanford University Press, Stanford; Oxford University Press, London. $3.00. 9 x 6; ix + 274; 1941.

Probably no one will seriously question the assertion that the second world war will some day come to an end. Many of those who have access to the public ear are advising that until that day all plans for the reconstruction of civilization be held in abeyance all unmindful of the possibility that the civilized world as we have known it may vanish before our eyes in the conflagration, leaving nothing to reconstruct. These misguided prophets also seem to forget that a cessation of hostilities following the cry "*vae victis*!" is no more likely to lead to an enduring peace now than it did a quarter century ago, and that a reconstructed civilization can be no more than a hypothetical abstraction unless its foundation can be laid before the ultimate outcome of the war becomes a certainty.

Therefore we may be thankful that two of the leading universities of the country have seen fit to celebrate the anniversaries of their founding by holding symposia for the consideration of the future of civilization.

It is interesting to observe how characteristically the personalities of the two institutions are reflected in their respective symposia. Rutgers University was founded 175 years ago by descendants of New Amsterdam Dutchman, who had a reputation for business acumen (at least that is the way that Peter Kalm represented them). The contributions to its symposium are engineers. This term has acquired a wider designation than its original denotation of one who runs an engine, and in these pages we meet the terms "biological engineer" and "agricultural engineer." These expressions indicate those who approach the problems of biology and agriculture with the mental attitude and precision of the trained engineer. These are not the men who make great scientific discoveries, but those who apply the fruit of scientific achievement to human welfare. They are the spiritual descendants, not of Swammerdam or Faraday, but of Pasteur and Clerk-Maxwell.

On the other hand, Stanford University is young by comparison. Established only a half century, it is still largely colored by the memory of its first president, David Starr Jordan, whose presence we still seem to feel when walking through its halls or under the eucalyptus trees of its campus. Although a great humanitarian, his pursuit of Truth was not prejudiced by any motive of materialism. Those who participated in this symposium with one exception, do not seek to reform the world, but to understand it. Reformation may be desirable and necessary, but understanding must come first.

The best essay out of the fourteen which comprise this book is always that which one is reading at the last time.

LANGUAGE IN ACTION.

By S. I. Hayakawa. Harcourt, Brace and Company, New York. $2.00. 7¾ x 5; ix + 245; 1941.

The Trivium of the Middle Ages consisted of Logic, Grammar, and Rhetoric. These terms were more broadly construed in those days than at present; logic was the art of thinking, and grammar and rhetoric were the arts of self expression by means of the written and spoken word. Anyone who has successfully mastered these subjects need not fear for his education in any company today.

Psychologists have long argued over the extent to which thought might be possible without language. Sub-human animals have thoughts, but to what extent do they *know* that they think? If conscious cerebration depends on language, does it not behoove us to try to understand the theory of language? Do we not need to know something about the use of language, instead of being satisfied merely to know how to make use of it—a very different thing?

It is said that Tallyrand, on negotiating an international treaty suggested that if it did not contain an ambiguity one should be inserted. But probably such a step was unnecessary as all language, especially the language of diplomacy, is by nature ambiguous. Not only do the same words convey different meanings to men in Timbuktu and Paramaribo, but they convey to the same individual a different meaning today from what they did yesterday or will tomorrow.

The only language which remains unchanged throughout the ages is profane language. The dead languages do not acquire new meanings, but they are full of ambiguities acquired when they were vital media of expression. In fact, probably the chief cause of mortality among languages is that, having reached the saturation point for ambiguity, they can acquire no more. As long as a language is a living thing it must exhibit the chief characteristic of all living things—incessant change.

During the past few years thoughts such as these have actuated numerous authors to produce books devoted to the discussion of the meaning of verbal expression. Unfortunately these books are for the most part expressed in such philosophical jargon that they illustrate the difficulties that they are intended to elucidate. The single exception seems to be the one now under consideration. It is logically conceived and lucidly written, and when the author resorts to expressions that would be ambiguous in less skilful hands the content always indicates what is intended. It is even pleasant reading and will be found especially helpful by any one who contemplates writing a book on any subject.

CARNEGIE INSTITUTION OF WASHINGTON. *Year Book, Number 40, July 1, 1940–June 30, 1941. With Administrative Reports through December 12, 1941.*

Carnegie Institution of Washington, Washington, D. C. $1.50 (cloth); $1.00 (paper). 9½ x 6¾; xxxii + 346: 1941.

Vannevar Bush says, in the President's report,

"The Carnegie Institute of Washington is so constituted that it is bound to be deeply involved in that aspect of the present intense national effort which is concerned with the application of natural sciences to national defense, and it is necessary and fitting that the Institution should respond fully to the call of government in this regard. Inevitably, therefore, many of its long-range programs of research in the field of pure science have now been changed or held in abeyance."

Concerning defense activities: "In order that the combined effort may be properly integrated, the President of the United States has, by Executive Order, created the Office of Scientific Research and Development as a part of the Office for Emergency Management, and has given this Office the task of coordinating all defense research, and, through its subordinate bodies, of supplementing the research of the Army and Navy in the development of instrumentalities of warfare, and in medical research connected with defense. The President of the Institution is Director of this Office, and many staff members are members of its organization."

Reports are given as usual, in the *Year Book*, on the progress and development of the different departments (astronomy, terrestrial sciences, biological sciences, and historical research). The Department of Terrestrial Magnetism is heavily engaged in research on governmental problems. In a limited space it is not possible to summarize the activities in the biological sciences and in historical research. Many of these have been reported in these columns from time to time. But we wish to call attention to Corner's interesting review of the program of the Department of Embryology, in which he says:

The past history of this Department, looked at from one point of view, is a brilliant example of a planned campaign, systematically conducted. It is indeed remarkable how many of the items of Dr. Mall's original "Plea for an Institute of Human Embryology" have been successfully executed. On the other hand, a list of the individual investigations mentioned in the successive Year Books might suggest that the advance was not always direct. What has been done has at times not even been embryology under standard definitions of the term, . . . Yet the general result has been an advance in our knowledge of embryology in the strict sense.

NOTES ON THE PREPARATION OF PAPERS FOR PUBLICATION IN *The Journal of Hygiene and Parasitology*.

By the Late G. H. F. Nuttall. Cambridge University Press, London; The Macmillan Company, New York. $1.15. 10¼ x 7; 62; 1940.

We highly recommend this little volume as an invaluable guide for the young research worker in the preparation of biological papers for publication. The late Doctor Nuttall, founder of two journals, the *Journal of Hygiene* and *Parasitology*, set a high standard for the writing of scientific articles. During the long period that he served as editor (*Journal of Hygiene*, 1901–1937; *Parasitology*, 1908–1937) he assisted many inexperienced writers in preparing and improving their manuscripts for the press, with the twofold aim of raising the literary workmanship of scientific journals and of relieving the editor and the press of much unnecessary work.

From the large collection of notes which Nuttall left pertaining to the many phases of the preparation of papers for publication, the present editors of Nuttall's journals, G. S. Graham-Smith and D. Keilin, have compiled this volume. They have omitted many notes of a specialized nature, such as technicalities in printing and illustrating, in order to produce a brief, concise guide useful to those who are entering the field of scientific writing. A complete mastery by the young author of the basic rules which are herein given will simplify all his future writing. Furthermore, he will learn something of the editor's problems.

Certain "Golden Rules" are listed that must always be followed, and suggestions are given for (1) the composition of a paper (a) from original notes, (b) first, second, and intermediate drafts with general instructions pertaining to headings, footnotes, quotations, abbreviations, bibliography, style and wording, illustrations, etc.; (2) sending manuscripts and illustrations to the editor; proof reading, reprints; and finally (3) the history of a paper is given after it has been sent to the editor. The index is a model which those whose ambitions extend to more formal writing may well follow.

Books of this type are important for biological libraries. The low cost of the present volume, however, makes it available to most individuals.

THE DAYS OF CREATION.

By Willy Ley. Modern Age Books, Inc., New York. $2.75. 8¼ x 5½; x + 275; 1941.

This book is an attempt to tell, in popular form, the story of the evolution of life on the earth beginning with the creation of the planet itself and continuing through to the present time. There are a number of things with which the specialist might find fault, as is probably inevitable in a popular book written by a non-specialist. However, the book is to be recommended in that it presents in many cases the evidence for the statements made. In a number of instances different theories are compared with an evaluation of the evidence for and against them. It approaches in this respect the technical writings of the professional scientist more closely than most popular books.

The book is not simply an attempt to chronicle the events in the history of life on the earth. It presents evolution as a dynamic process with emphasis on cause as well as on effect. The treatment of the causes of evolution includes a very much simplified and not too satisfactory version of the contributions of modern genetics to this field. In general the treatment of causative factors is not as satisfactory as the description of the events. Nevertheless it should give the lay reader the thought that evolution is not something that inexplicably happened.

For some reason, the author has built the book around an attempt to compare the history of evolution with the story of creation according to the book of Genesis. He makes much of this in the introduction, and the book is divided into chapters headed The first day, The second day, etc. However, this purpose seems to have been almost completely forgotten in writing the individual chapters, for only a very few paragraphs have been devoted to it. It seems to have been used as a framework by which to outline the book and then to have been put aside.

There is an index of five pages and a number of fairly good drawings, some of which are taken from illustrations in well-known scientific works.

A NEW EARTH AND A NEW HUMANITY.

By Oliver L. Reiser. Creative Age Press, New York. $2.50. 8 x 5; xiv + 252; 1942.

This treatise might well have been entitled "A New Philosophy for the Average American." The central theme around which this discourse revolves is that our scientific and technological progress has so outstripped our ethical and social progress that we find ourselves as a race heading certainly and rapidly for extinction unless some drastic change is brought to bear on world conditions. A factor contributing strongly to this situation is the confusion and uncertainty characteristic of our modern system of education. This weakness of our educational system has been in a large measure the direct result of disagreement over *what* should be taught in our schools, and *how* it should be taught. Another contributing factor to our failure in ethical and social progress is that we have not applied enough of the scientific method to these realms of human endeavor. In this connection, the author feels that it is well to remember that the essence of the scientific method is freedom in word and action and that the final authority rests not with a man or an accepted point of view, but with the experiment. It is the belief of the author that when the scientific method is more thoroughly applied to the development of governmental systems, world economy, and social behavior, then and *only then* can we hope to bring any sort of order out of the present chaos. Since America alone retains some vestige of freedom, the author believes that the American people have a great responsibility in shaping the future destiny of world civilization.

The discussion is timely, and although it may appear to some readers to be slightly tinged with war-time propaganda, we believe that the author is entirely sincere in his viewpoint, and that he has given a great deal of honest, unemotional thought to present world conditions.

The work carries a 25-page index.

THE ARCH LECTURES. *Eighteen Discourses on a Great Variety of Subjects Delivered in New York during the Winter of 1940.*

By Claude Bragdon. Creative Age Press, Inc., New York. $2.00. 8 x 4⅞; vii + 239; 1942.

The author, an architect by profession, and an educator and philosopher by inclination, here presents a series of discussions which he gave before "The Friends of Carman Barnes Club" in New York City. These lectures, like much of Bragdon's other writings, expound in sincere and convincing manner the so-called "new philosophy" of education, which would supplant the rather mechanistic and materialistic present methods and procedures with other methods and procedures designed to educate the young by stimulating and developing the imagination, the spirit, the aesthetic and cultural senses. With much of the material covered by these lectures the average intelligent reader will disagree violently, but he cannot help but find the author's presentation challenging and enlightening. In certain respects, it is to be hoped that parts of this book will prove to be prophetic. Some of the more interesting lectures are concerned with: yoga, the fourth dimension, symbols and sacraments, archetypes, art and the machine age, skyscrapers, harnessing the rainbow, the theatre, footprints of the eternal fugitive, the ritual of play, the androgyne, modern idolatries, and Emerson—the mouthpiece of the American spirit.

There is neither index nor bibliography, but the book is illustrated with a number of very fine photographs. This reviewer recommends the volume to thoughtful and progressive-minded readers, who will doubtless find in it a picture of the type of world we could all have if we were only willing and able to rise from our present grossly materialistic level of living to the higher plane of the idealistic.

BASIC LABORATORY PRACTICE: *An Elementary Manual of Fundamental Technic.*

By Norman G. Sprague. Chemical Publishing Company, Brooklyn. $3.50. 8½ x 5½; ix + 124; 1941.

This book is a new type of chemical laboratory manual

designed to accompany any laboratory course book. The author here gives concise and collected form to numerous elementary details and instructions of laboratory behavior and technique which are not usually found in one place, and many of which are probably gathered only by word of mouth. The purpose is twofold: to aid the instructor in a burdensome, though important, task, and to give the student the continual detailed instruction in good laboratory technique which is so vital to success. The manual is in no way a collection of trick methods, "kinks", short-cuts, or improvisations. The student is expected to use a little originality, and the instructor to present better methods, if he knows them. The arrangement of the contents is as follows: rudiments of behavior and technique, preparation of some very simple and essential equipment, some general operations with liquids and solutions, filtration, dishwashing, drying and absorption apparatus, use of the chemical balance, a few volumetric manipulations, and chemicals that entail special difficulties and dangers. The author concludes with a discussion of study, including study habits, literature of chemistry, notebooks, reports, the spoken word, and honesty. The book is appropriately illustrated with photographs and drawings, which add greatly to its value for the student, and concludes with an index. There is little doubt but that this manual will be a real boon to the chemistry instructor and of invaluable assistance to the student throughout his entire chemistry course.

PHOTOGRAPHY: *Its Science and Practice.* *By John R. Roebuck and Henry C. Staehle. D. Appleton-Century Company, New York and London.* $5.00. 8¾ x 5½; xv + 283; 1942.

The present volume is a survey of the modern science of photography as it is understood and practiced today. Topics such as the nature of the photographic emulsion, exposure and development, color sensitivity, chemistry of the photographic process and positive processes such as printing, enlarging, and the making of lantern slides, etc., are treated in detail. The latest views on the mechanism of image formation are presented in a chapter entitled "Theory of the latent image," and one chapter is devoted to lenses and the optical aspects of photography. Of considerable interest is the account given of the principles involved in the various processes of color photography. Since the object of most photography is to obtain good pictures the authors have very appropriately given us, in a final chapter, many practical suggestions as to composition.

A very useful laboratory manual of practical experiments and a general bibliography conclude the volume.